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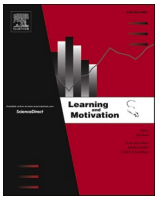

Types of errors in Raven tests in a population with Down syndrome: An online assessment

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ABSTRACT

The objective of this study was to describe the types of visuoperceptual errors on Raven tests in a sample of Mexican people with Down syndrome (DS), and to explore whether these errors were related to mental age (MA) or chronological age (CA). Participants included 50 people with DS, with a mean CA of 19.47 years and a mean MA of 7.40 years. The Raven Colored Progressive Matrices test was used to obtain the MA and also to analyze four types of errors: 1) difference, 2) figure repetition, 3) inadequate individuation, and 4) incomplete correlates. The study was carried out online due to the COVID-19 pandemic. Participants made an average of 22.84 errors on a total of 36 items. No predominance was found of any of the four types of errors. However, MA was negatively correlated with three error types. Because there are similar proportions of the four errors, the results do not allow us to define a specific perceptual deficit profile; errors on the test could be the result of general difficulties in the organization of perceptual information. Future studies could investigate whether this pattern of results is related to cognitive abilities such as working memory or executive functions.

1. Introduction

Down syndrome (DS) is a genetic alteration caused by a triplication of chromosome 21, resulting in a particular phenotypic, genotypic, physiological, and cognitive profile (Grieco et al., 2015). In Mexico, the incidence of DS is around 3 cases per 10,000 births, according to an analysis of birth and death certificates from 2008 to 2011 (Sierra-Romero et al., 2014). The specific cognitive profile includes alterations in language (Chapman et al., 1991; Katsarou & Andreou, 2017; Mervis & Robinson, 2000), working memory (Godfrey & Raitano Lee, 2018; Jarrold & Baddeley, 1997; Vicari et al., 2004), perceptual abilities (Saviolo-Negrin et al., 1990; Wan et al., 2015), and executive function abilities (Daunhauer et al., 2014; Onnivello et al., 2022; Rowe et al., 2006; Tungate & Conners, 2021).

One of the instruments commonly used to measure intellectual abilities is Raven's Progressive Matrices Test, given its practicality, validity, and short administration time. The test has four versions: Simpler Standard Progressive Matrices (SPM), Advanced Progressive Matrices (APM), Colored Progressive Matrices (CPM), and Raven's 2 (the latter measures educational capacity, that is, the ability to establish relationships and patterns from non-obvious information). The CPM is a non-verbal task used by psychologists and neuropsychologists for the diagnosis and evaluation of cognitive abilities in people with typical and atypical development. It measures the ability to generate analogies and relationships between perceptual elements, exploring the ability to make comparisons, reason by

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analogy, and organize spatial perceptual information into a systematically related whole (Vodegel Matzen et al., 1993). Although the scores have traditionally been based on the number of correct answers, analysis of the errors could provide valuable information about the problems people with DS have with analogies, cognitive strategy, and perceptual processing.

The present study uses error classifications as defined in three prior studies that have analyzed the frequency of errors on Raven tests. Vodegel Matzen et al. (1993) analyzed Raven test errors in a sample of typically developing (TD) Dutch children, aged 8.5–12.5 years, and found that the most common type of error was incomplete correlate, followed by wrong principle, figure repetition, and additional elements. This pattern of results occurred in children with mean and below mean scores, but not in those with scores above the mean.

Kunda et al. (2013) analyzed the types of errors on Raven tests by two groups of children, TD and autistic, aged 10–11. The results were compared with those obtained using the ASTI computational model, whose objective is to inquire about resolution strategies and mental representations during the execution of Raven tests. The results showed that the largest number of errors was of the wrong principle type in both groups, followed by figure repetition, difference, and incomplete correlation. However, the authors recognize that their classification of errors could be problematic because it lacks a systematic methodology and could not be extended to analyze errors in the color version of the test.

In a novel study by Vakil and Lifshitz-Zehavi (2012) of 23 adults with non-specific intellectual disability (NSID), 15 adults with DS, and 35 children with TD matched for mental age, participants were administered the CPM and SPM adapted into a visual tracking task, where their responses were recorded through eye movements. The results showed a higher number of responses for the TD group, which spent more time than the NSID and DS groups exploring the response options. There were no differences between the NSID and DS groups. The authors interpret the results as suggesting that participants in the three groups use different resolution and constructive matching strategies.

A few studies have focused on analyzing the types of visuoperceptual errors made on Raven tests by people with DS. Gunn and Jarrold (2004) examined three groups of participants, one with DS, one with learning disabilities, and one with TD, and found that the three groups made similar numbers of errors, but not of the same type. People with DS made a higher proportion of figure repetition errors, followed by inadequate individuation, incomplete correlates, and difference errors. The authors argue that the type of errors made could refer to perceptual information integration problems or to recognition and memory difficulties inherent to DS.

Error types on the Raven test have also been analyzed in typical adult populations with emotional or addiction disorders (Fracchia et al., 1970; Jurjevich, 1967). Jurjevich (1967) found moderate associations between the number and types of errors made on Raven tests and some emotional disorders, as defined with the Minnesota Multiphasic Personality Inventory (MMPI), including those characterized with the schizophrenia, psychopathic deviate, anxiety, and depression scales, in young people with TD who were approximately 23 years of age.

Few studies, however, have advanced interpretations of the patterns of errors made on Raven tests. The importance of such interpretations is that they would allow us to understand the cognitive problem-solving strategies people use when they perform this test. It would be especially useful to investigate the types of errors made by atypical populations, such as those with intellectual disabilities and those with DS. The cognitive difficulties these people experience have been studied mainly at the level of language, memory, and executive functions, but not in terms of perceptual skills or mental organization, which are measured by Raven tests. No studies of this type have been carried out in the Mexican population with DS. The population with DS has not received regular formal education, so it would be interesting to know if their recreational and occupational education has an effect on their visuoperceptual processing or spatial reasoning. The objective of this study was thus to describe the type of visuoperceptual errors made on Raven tests by Mexican people with DS and explore whether they are related to their mental or chronological age. The research question is to understand the nature of the visuoperceptual processing of people with DS, and the cognitive strategies they use when solving a task that involves generating analogies, comparisons and spatial reasoning between geometric elements. This study aims to provide information that can contribute to educational intervention programs to improve the skills that are compromised in people with DS.

2. Method

This study was exploratory, correlational, and cross-sectional, and was carried out online.

2.1. Participants

Participants were recruited through advertisements published on social media and in special care centers for people with DS in Mexico City and other parts of the country. Fifty people with Down syndrome aged 11.41–30.66 years old ($M = 19.47$, $SD = 4.92$; 24 female, 26 male) participated in the study. Their mean MA was 7.40 ($SD = 2.72$). No age group was represented more frequently. Six (12 %) of the participants were ill with SARS-CoV-2 but had a favorable recovery without apparent physiological sequelae. None had medical or psychological comorbidities or hearing or vision problems. Given social distancing requirements during the COVID-19 pandemic, all were tested in individual Zoom sessions that were facilitated by their parents or guardians. All participants attended a special private school for Down syndrome with an occupational and recreational focus. They had a medium socioeconomic level according to a sociodemographic questionnaire administered to their parents; 36 % lived in single-parent homes and the remaining 64 % in two-parent homes. All were monolingual. The project was approved by the Bioethics Committee of the Facultad de Estudios Superiores, Zaragoza (Approval No. FESZ-CE/21–116–20).

2.2. Materials

A questionnaire consisting of 30 items was used to assess whether participants met inclusion or exclusion criteria regarding illnesses and disorders, educational activities, socioeconomic level, and general development). The CPM Raven test was used to obtain the mental age and the analysis of perceptual errors; this test has been standardized for the Mexican population with a reliability of 0.96 (Ravenet al., 1993). The task is typically performed with 36 cards, divided into three series of 12 cards (A, AB, B), each card containing a figure with a geometrical pattern, with each series following a progressive rule. The three series have increasing levels of complexity of the geometric patterns.

2.3. Procedure

The tasks were carried out in a Zoom session on a laptop or desktop computer; all sessions were held between 10 a.m. and 5 p.m. First, the sociodemographic questionnaire was administered to one of the participants' parents or primary caregivers in a Zoom video call that lasted 20 minutes. Second, the CPM Raven test was administered to participants in a semi-automated PowerPoint presentation containing the 36 cards, presented one by one in order of complexity. Each geometric figure has a missing element, a "hole," which the test-taker is asked to locate among six response options. The instructions given to participants in our online version were as follows: "Look carefully at all the pieces that are shown [examiner points at them] and use the Zoom control to click on the one you think should go in the hole. Verbal responses were not taken into account, as these could be biased ambiguous. The task had no time limit but was discontinued after five consecutive errors. Responses were recorded by the examiner on an answer sheet. A parent or guardian was present during the evaluation to facilitate the technical details of recording the Zoom session; however, they were asked not to interfere during the task or make approving or disapproving gestures. They were also asked to eliminate, as far as possible, external distractors in the room where the task was performed and ensure a quiet environment. The average duration of the tests was 23 minutes.

3. Statistical analysis

The mental age of the participants was obtained following the reference tables shown in Raven et al. (1993) through descriptive and normal distribution analysis. The four types of errors described in that reference were grouped and classified by frequency because this information describes the perceptual errors found by Raven tests. Given the level of measurement of the error frequencies obtained, the comparative and correlational statistical analyses were carried out with non-parametric tests: the Friedman test and the Spearman correlation coefficient, respectively.

4. Results

The research question of this study was to understand the relationship between types of visual-perceptual errors in people with DS and their mental and chronological age. Their errors were thus counted and classified qualitatively according to the four types described by Raven et al. (1993). These are: 1) difference: the participant selects a figure with a completely unrelated pattern (the underlying cognitive processes are attention, concentration, visual discrimination, working memory, and inhibition); 2) figure repetition: the participant chooses a figure that merely copies the pattern adjacent to the hole (the cognitive processes involved are sustained attention, working memory, and eye-motor coordination); 3) inadequate individuation: the participant chooses an option with only half of the correct pattern (the cognitive processes involved are sustained attention, visual discrimination, and inhibitory control); and 4) incomplete correlates: the participant correctly identifies part of the correct figure, but it is incorrectly oriented or rotated (the underlying cognitive processes are rotation, spatial visualization, and cognitive flexibility). Table 1 shows the means for types of errors, the number of errors per series, the total numbers of correct answers and errors, the ages of participants, and the response times.

Table 1
Chronological Age, Mental Age, Correct Answers, and Errors on Raven tests.

Variable	Mean	Standard Deviation	Range
Chronological age	19.47	4.92	11.41–30.66
Mental age	7.40	2.72	4–14
No. of correct answers	13.14	5.29	3–25
No. of difference errors	5.40	3.24	0–14
No. of repetition errors	6.16	2.66	1–12
No. of inadequate individuation errors	6.14	2.45	1–12
No. of incomplete correlate errors	5.14	2.08	1–9
Total errors	22.84	5.77	11–33
No. of errors in "A" series	6.98	2.60	2–11
No. of errors in "AB" series	7.38	2.52	2–12
No. of errors in "B" series	8.48	1.61	5–12
Response time (minutes)	23.28	14.56	7–90

5. Comparative analysis of errors

A comparative analysis was carried out of perceptual errors to determine the perceptual processing strategies that participants used and assess where they needed further development. The mean numbers of each error type were analyzed for significant differences. Given the level of measurement and the non-normalized distribution of the variables, a non-parametric analysis was performed with the Friedman test. The results showed that differences between the four types of errors were non-significant ($X^2 = 3.73$, $df = 3$, $p = .292$; see Fig. 1). Similarly, the number of errors per series was compared with the Friedman test. Here there were statistically significant differences: as the complexity of the geometric patterns increased, the participants made more errors ($X^2 = 17.17$, $df = 2$, $p < .001$; see Fig. 2).

6. Correlational analysis of errors on Raven tests

To explore the relationship between chronological age, mental age, and correct answers, total errors, types of errors, and series errors, a non-parametric statistical analysis was performed with Spearman's *r* correlation coefficient. The results are shown in Table 2.

Table 2 shows significant negative correlations between the mental age of the participants and error 1 (difference), error 2 (figure repetition), error 4 (incomplete correlates), and the complexity of the series A, AB, and B. The strongest correlation was between MA and error 1, (difference; $r = -.611$, $p < .05$), where a greater mental age is correlated with fewer errors leading to the choice of completely unrelated patterns. In other words, errors related to visual discrimination and inhibition are reduced when cognitive performance increases. There are no significant correlations with chronological age, implying that mental age is a better indicator of perceptual skills.

7. Discussion

The objective of this study was to identify the types of errors made on the Raven CPM test by people with Down syndrome. The errors were divided into the categories described by Raven et al. (1993): difference, figure repetition, inadequate individuation, and incomplete correlates. The 36 test items were presented in an online assessment, in three series of 12 items each. Participants with Down syndrome made an average of 22.84 errors, with similar numbers for each of the four types of errors (approximately five to six). Although no statistically significant differences were found between the types of errors, the most common was figure repetition. Significant differences were found between the number of errors made in the three series, with the largest number of errors in series B. These results can be interpreted as meaning that the greater the complexity of the items, the more errors participants will make.

Notably, however, the number of errors is similar for all four types, which could mean that the different types of complexity posed by the task create similar levels of difficulty, resulting in the choice of inconsistent, missing, rotated, or incorrect options by people with DS. The errors on a Raven test represent difficulties in the organization of perceptual information contained in geometric patterns or in the elaboration of analogies (Vodegel Matzen et al., 1993). Our results do not suggest that people with DS show deficits related to particular types of errors, although they do indicate that patterns of perceptual complexity increase the presence of errors in participants' performance.

Our analysis found no correlation between the chronological age of participants and the number or types of errors they make; that is, there is no relationship between performance on Raven tests and the experience of people with DS with the surrounding world. However, statistically significant moderate and high negative correlations were found between mental age and the number of errors, errors per series, and types of errors (except for inadequate individuation). These negative correlations indicate that the greater the cognitive development of people with DS, and the more advanced their intellectual age, the fewer errors they make. In other words, the effects of their learning and maturational development can be seen. The mental age variable is negatively and significantly related to

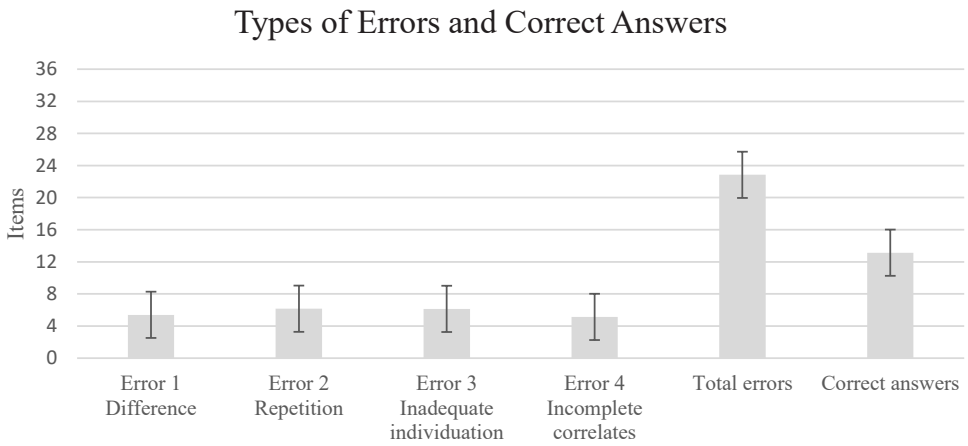

Fig. 1. Correct Answers, Total Numbers of Errors, and Classification According to Raven et al. (1993).

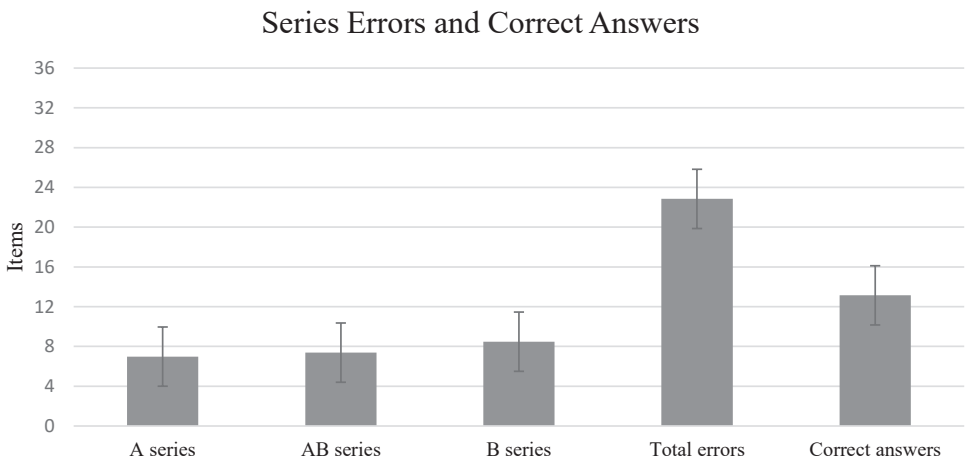

Fig. 2. Correct Answers, Total Number of Errors and Classification by Series.

Table 2
Spearman's *r* Correlation Analysis of the Relationship Between Chronological Age, Mental Age, and Correct Answers, Total Errors, Types of Errors, and Series Errors.

	CA	MA	Correct answers	Total errors	Error 1	Error 2	Error 3	Error 4	A series	AB series	B series
CA	-	-	-	-	-	-	-	-	-	-	
MA	.109	-	-	-	-	-	-	-	-	-	
Correct answers	−.018	.818**	-	-	-	-	-	-	-	-	
Total errors	.015	−.818**	−1.000**	-	-	-	-	-	-	-	
Error 1	−.064	−.611**	−.742**	.740**	-	-	-	-	-	-	
Error 2	.038	−.487**	−.562**	.568**	.125	-	-	-	-	-	
Error 3	−.001	−.244	−.339**	.335**	.095	−.050	-	-	-	-	
Error 4	.005	−.435**	−.440*	.440**	.264	.148	−.260	-	-	-	
A series	.013	−.771**	−.852**	.851**	.650**	.414**	.301*	.467**	-	-	
AB series	−.014	−.694**	−.867**	.870**	.654**	.507**	.351*	.290*	.560**	-	
B series	−.081	−.710**	−.832**	.831**	.579**	.585**	.154	.437**	.660**	.658**	-
Response Time (minutes)	.763	.288	.864	.876	.529	.812	.389	.647	.749	.708	.445

* $p < .05$;
** $p < .01$

the perceptual performance of the participants, which is not the case with chronological age, suggesting that perceptual abilities are not inherent to biological development, but to maturity. The strongest correlation was between MA and error 1 (difference), implying that a greater mental age contributes to fewer choices of completely unrelated patterns. In other words, improvement in inhibition could also improve executive functioning (Zelazo & Müller, 2011).

Analysis of the types of errors made in each of the three series found the highest negative correlation between MA and performance in series A. Fewer errors are made in series A at more advanced cognitive ages, probably because these are the least complex items. Lower correlation coefficients were found for series AB and B, probably because they include items that are visually more complex.

No correlation was found between response time and type of error or series, which could indicate that the average time that a person with DS invests in completing Raven tests is not linked to their performance. That is, they do not take longer to select a response even with complex perceptual patterns.

Gunn & Jarrold (2004) found a significant predominance of figure repetition errors and almost no difference errors. They also found no significant correlation between the figure repetition error and the chronological age of their participants with DS. They interpret the predominance of figure repetition as a strategy for partial resolution of the task, the choice of a similar trait that is close to the missing element. However, this difficulty was not specific to people with DS: the pattern was similar in their control group.

Our results could be compared with those of Kunda et al. (2013), although their sample included children with autism and they used a different categorization of errors. They found a predominance of "wrong principle" errors, defined as those where the test-taker fails to understand the logical relationship of the items and chooses an option that is merely a copy or a combination of elements from the figure presented. In our study, however, there is no predominant type of error, suggesting that there is no prioritized strategy.

Our results contradict those reported by Vodegel Matzen et al. (1993), who found a greater presence of the incomplete correlates error, although it was found in children with TD and not with DS. This raises the question of whether perceptual strategies occur in the same way in typical and atypical populations. Vakil & Lifshitz-Zehavi (2012), who used a visual tracking adaptation to compare the

performance on Raven tests (CPM and SPM) of people with intellectual disability, DS, and TD, found more correct items and longer visual response times for the typical than for the atypical groups. They interpret this result to imply more strategic responses for the typical group than for the atypical groups whose performance was similar.

A limitation of our study is that the online administration of Raven tests may have influenced participants' response times; however, it was a necessary procedure, given the restrictions during the COVID-19 pandemic. Another limitation is that, given the circumstances of online evaluation during the pandemic, it was not possible to determine whether the participants' performance was influenced by emotional regulation issues, undiagnosed or untreated psychological disorders, or social isolation. Future online studies could make comparisons with our study to determine whether participants' performance follows the same pattern.

Future research could also include a control group to compare participants with DS with a typical group matched either by mental or chronological age, as well as measurement of cognitive abilities such as language, working memory, and executive function, which could influence the type of errors made on Raven tests. Planning or organization skills, for example, could affect participants' strategies. Likewise, the type of errors made in different age groups could also be analyzed to determine whether there are variations with respect to brain development or maturation.

This is the first study of Mexican people with DS that analyzes the errors made on Raven tests in order to understand the types of perceptual information that present difficulty in processing. This sample of participants with DS was not formally educated, but future studies could also study the influence of education on performance. The results from this and future studies could form the basis of educational intervention programs for people with DS, focused on enhancing the perceptual abilities represented by each of the four types of errors, and also on improving cognitive skills underlying perceptual abilities, such as working memory, sustained attention, cognitive flexibility, behavioral inhibition, rotation, and spatial visualization (Natsopoulo et al., 2002). In this way, educational and clinical intervention programs could be developed, utilizing exercises in completing figures and analyzing the relationships between visual patterns.

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CRediT authorship contribution statement

J.B. Barrón-Martínez: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. **J. Salvador-Cruz:** Data curation, Formal analysis, Funding acquisition, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft.

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