World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

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Assessment of primary schoolchildren's fluid intelligence using Raven's Colored progressive matrices: A pilot cross-sectional study in Lebanon

Marwa Manana [1], Diana Ghanem [1], Sarah Tarhini [1], Lina Ismaiil [1], Rana Sabra [1] and Georges Hatem [1, 2, *]

[1] *Clinical and Epidemiological Research Laboratory, Faculty of Pharmacy, Lebanese University, Hadat, Lebanon.*
[2] *EPI Unit - Institute of Public Health, University of Porto, Rua das Taipas, n° 135, 4050-600 Porto, Portugal.*

World Journal of Advanced Research and Reviews, 2023, 19(03), 317–326

Publication history: Received on 26 July 2023; revised on 06 September 2023; accepted on 08 September 2023

Article DOI: https://doi.org/10.30574/wjarr.2023.19.3.1801

Abstract

This study aims to assess children's reasoning ability, namely following the crises in Lebanon, and to identify those in need. A pilot study was conducted in April-May 2023, targeting children between 6 and 11 attending grades 1 to 5. The sample (130 students) comprised more females (60.5%) than males (39.5%). The score for simple pattern completion was significantly higher among students aged 8-11 (9.58 over 11) than their younger peers (8.38; p=0.007). This score showed statistically significant variation depending on the student's grade, with the lowest score at grade 1 (6.88), which significantly increased at grade 2 (9.44) and attained its maximum value at grade 4 (10.72), then decreased again at grade 5 (9.03; p<0.001). Male students (9.33) had higher scores than females (8.84) with no statistical significance (p>0.05). The parent's characteristics did not statistically affect these scores, but students with older and married parents and those with better economic situations had higher scores. The score in discrete and continuous pattern completion was significantly higher among older students (10.68) than their younger peers (7.24; p<0.001) and per grade increase. Educators can support the development of fluid intelligence in schoolchildren through activities that encourage problem-solving, critical thinking, and creative exploration.

Keywords: Children; School; Intellectual ability; Intelligence

1. Introduction

Human Intelligence is the general ability of the mind to learn, solve problems, and have the right reasoning approach, incorporating several cognitive functions such as awareness, attention, memory, language, or planning (Colom et al., 2022). Among others, abstract thinking or fluid intelligence reflects humans' capacity to solve problems, reason, and think critically (Ren et al., 2020). It is not innate, as it is linked to cognitive ability that develops during childhood when children start experiencing new experiences, skills, and capabilities (Kretzschmar et al., 2022; Ren et al., 2020). It develops with age while acquiring new abilities, knowledge, and experiences. At school age, these functions can be assessed through the ability to solve problems, such as figure classifications, analyses, number and letter series, matrices, and paired associates (Wang & Deng, 2022). Abstract reasoning assessment provides a reliable scale of the general intelligence measurement. Several factors, such as genetics, cognitive development, environment, education, and creativity, can affect this capacity. However, all these factors influence the ability of each individual, thus resulting in differences in fluid intelligence between one individual and another (Colom et al., 2022; Sternberg, 2019).

Recent research reported a possible link between children's intelligence and reasoning to genetics at certain cognitive levels and brain structure measures (such as brain volume and grey and white matter volume) (Deary et al., 2022). Continuous development results from the evolution of cognitive abilities due to unceasing environmental interaction, with a significant role of education in an individual's analytical skills (Lövdén et al., 2020; Mutiani et al., 2021). A family's

* Corresponding author: Georges Hatem.

socioeconomic status can significantly affect a student's reasoning ability due to the financial ability to attend better institutes (Peng & Kievit, 2020). Creativity and critical thinking have a positive correlation, which has an evident impact on the student's academic performance (Akpur, 2020). Abstract Reasoning is the main drive of thinking outside the box, troubleshooting, decision-making, innovation, research, and a valid link between ideas and events. Developing it can help foster the individuals' innovative and creative ability and intellectual capacity (Colom et al., 2022; Nur & ALGHADARI, 2021). Abstract reasoning or fluid intelligence can be applied to school children or employees to help them develop and achieve better goals throughout their education or work tasks (Johann et al., 2020; Syawaludin et al., 2019). Fluid intelligence is elaborated by linking different components of cognitive process, also known as integration of mental activity, which can improve attention and enhance innovation (Duncan et al., 2020).

Lebanon faces several crises due to the combined effect of hyperinflation, national currency devaluation, and the coronavirus pandemic impact, leading to a drop in the citizen's minimum wage and a significant elevation in the poverty rates (Hatem & Goossens, 2022; Mawad et al., 2022). Many students can no longer afford to attend expensive schools and have decided to stop or transfer to low-cost schools. Moreover, the pandemic, inducing remote interaction with the teachers, affected some students' performance and quality of life (Baten et al., 2023). This pilot study aims to assess children's reasoning ability, namely following the crises in Lebanon, to identify those in need and develop supportive solutions accordingly.

2. Methods

2.1. Study Design

A cross-sectional pilot study was conducted over two months, April-May 2023, targeting children from a private school in an urban area in Lebanon. The study protocol is publicly accessible and was registered in the clinicaltrials.gov registry (NCT05870085) before data instigation.

2.2. Study sample

Students from age 6 to age 11 attending grades 1 to 5 were included. They were considered potential participants if they attended the same school at least one year before the data collection period. The sample size was calculated using a formula developed by Viechtbauer et al. (Viechtbauer et al., 2015) for pilot studies. It yielded a minimum sample of 130 students with a 95% confidence interval, a precision of 2.5%, a power of 80%, and a 10% loss to follow-up.

2.3. Study tool and data collection

The parent/legal guardian of each student completed the general characteristic data. These data comprised their age and the child's age, sex, grade, marital status, highest level of education, perceived economic situation, working and smoking statuses, and the total number of children. The Raven's Colored Progressive Matrices (RCPM) test was administered individually, without a time limit, using an electronic tablet, according to Raven's procedure (Raven & Court, 1998). Children were requested to select the missing element from six options in a drawing. One point was given per correct answer, and the total score was the sum of the correct answers, with a maximum score of 36. Trained pharmacists and a social worker approached the students during the school day and asked them to complete the test after explaining it without providing any assistance. The test took, on average, 50 minutes.

2.4. Ethical considerations

The study protocol, tool, and consent form were reviewed and approved by the scientific committee of the Lebanese University faculty of pharmacy (reference: 3/23/D). An initial meeting with the school management and teachers was performed to inform them about the study's objectives. After minimal changes, written approval was obtained from the school direction. Students were coded by the school's direction to preserve the anonymity of the results. Written informed consent was provided by the parents/legal guardians of the students. A small survey was sent to parents to provide their consent after reading the study goals and filling out the general characteristics of the students. Parents and students were acknowledged that their participation was voluntary and that they could withdraw it at any point of the study with only provided answers registered. No financial incentives were provided to the school management or team. Nevertheless, goody bags were distributed to all the students at the end of the data collection. Results were considered for research purposes only.

2.5. Statistical Analysis

Statistical analyses were performed using Statistical Package for Social Sciences (SPSS Inc, Chicago, Illinois) Version 29. The general characteristics of the students and the intellectual capacity classification are presented using frequencies

and percentages. The student's age and the person filling out the questionnaire, the total RCPM score per age group, is presented through mean and standard deviation. The different items were classified into three factors as recommended (Smirni, 2020). The bivariate analysis assessed the relationship between the total score per factor and the overall obtained score with the participants' general characteristics. One-way analysis of variance (ANOVA) was used to compare the mean scores between associate categorical variables. A p-value of less than 0.05 was considered statistically significant. The intellectual percentile distribution was computed and divided into six categories ranging from Intellectually superior to intellectually impaired (Table 1) (Smirni, 2020). Percentile categories were assessed per student age group from age 6 to age 11. As the student's age increases, the intellectual capacity for each category increases.

Table 1 Intellectual Capacity Percentile Distribution as compared to students' age

	Age (years)					
Percentile	**6**	**7**	**8**	**9**	**10**	**11**
95	20	21	24	27	29	30
90	18	19	23	25	28	29
75	13	16	20	23	25	27
50	10	12	15	20	23	24
25	8	9	10	15	19	20
10	6	7	8	10	14	17
5	5	6	7	8	10	15
≥95th	Intellectually superior					
≥75th	Definitely above-average in intellectual capacity					
≥50th	Greater than median					
25th-75th	Intellectually average					
≤25th	Definitely below-average in intellectual capacity					
≤5th	Intellectually impaired					

Results are presented through Percentile Distribution

3. Results

3.1. General Characteristics of the study sample

Table 2 displays the general characteristics of the sample under study. In the current study, students in Grades 1 to 5 were in scope. Students had an average age of 8.6 (1.5) years, with more females (60.5%) than males (39.5%). Children's parents' average age was 39.7 (6.2) years, with a high percentage of married (90.0%) and only 10.0% divorced or widowed. Most parents were non-smokers (70.9%). Their highest educational level was as follows: 45.0% held a university degree, 41.7% held a high school degree, and 13.3% only attained an elementary education. Sixty-one percent of the students had one of the parents working, 31.4% had both parents working, and 7.4% had non-working parents. Around three-quarters of parents reported an average economic situation (75.5%), while the remaining percentage corresponds to poor perceived status. Almost 13% of parents had only one child, 46.0% had two children, 31.4% had three children showed 31.4%, and the remaining (9.1%) had four or more children.

3.2. Assessment of students' fluid intelligence and abstract reasoning abilities

Table 3 displays the mean scores and standard deviations of the correct answers per year of age (6 to 11), considering the items clustering by the three factors. Comparable overall scores were found in factors III and I, while a significantly lower score was obtained for factor II. Factor III included items requiring a simple pattern completion. A higher score was noticed per increase of age, namely from 6 to 10 years, with the lowest score at six years (6.80 (2.74)) and the highest at ten years (10.14 (1.41)). The factor I comprised 15 items encompassing continuous and discrete pattern completion. Students 6 years of age scored 4.40 (3.27), significantly lower than their older peers. In contrast, those aged

9 and 10 had significantly higher scores (around 11 over 15). The last factor included ten items regarding closure and abstract reasoning. Children of 6 or 7 years had comparable scores (around 1.90 over 10), and those of 10 and 11 had a score of around 3.70.

Table 2 Distribution of the baseline characteristics of the participants

		Total (N=130)
General characteristics		**Frequency (%)**
Age of the student (years)	**Mean (SD)**	8.6 **(**1.5)
Age of the parents (years)	**Mean (SD)**	39.7 (6.2)
Relationship with the student	Mother	100 (82.6%)
	Father	21 (17.4%)
Sex	Male	51 (39.5%)
	Female	78 (60.5%)
Grade	Grade 1	28 (21.5%)
	Grade 2	19 (14.6%)
	Grade 3	28 (21.5%)
	Grade 4	29 (22.3%)
	Grade 5	26 (20.0%)
Marital status of the parents	Married	108 (90.0%)
	Divorced/Widowed	12 (10.0%)
Highest level of education	Elementary school or less	16 (13.3%)
	High school	50 (41.7%)
	University or more	54 (45.0%)
Economic situation	So poor	4 (3.4%)
	Poor	24 (20.2%)
	Average or more	91 (75.5%)
Working status	Both parents work	38 (31.4%)
	One parent works	74 (61.2%)
	Both parents do not work	9 (7.4%)
Smoking status	Smoker	34 (29.1%)
	Non-smoker/Ex-smoker	83 (70.9%)
Total number of children	One child	16 (13.2%)
	Two children	56 (46.3%)
	Three children	38 (31.4%)
	Four children or more	11 (9.1%)

Results are given in frequency (%: percentage) or Mean **(**SD: Standard Deviation).

Table 3 Mean and standard deviation of RCPM scores, according to the three-factorial clustering in each age group

Age	**Simple pattern completion Factor III**	**continuous and discrete pattern completion Factor I**	**Closure and abstract reasoning Factor II**	**Total score**
	Mean (SD)	Mean (SD)	Mean (SD)	Mean (SD)
6	6.80 (2.74)	4.40 (3.27)	1.90 (1.10)	13.10 (5.80)
7	7.86 (3.00)	6.43 (4.19)	1.91 (1.09)	16.19 (7.21)
8	9.50 (1.67)	9.13 (2.76)	2.63 (1.81)	21.25 (4.27)
9	9.31 (2.83)	11.08 (3.61)	3.69 (2.56)	24.08 (7.86)
10	10.14 (1.41)	11.21 (4.29)	3.62 (2.94)	24.97 (7.62)
11	8.73 (1.68)	8.36 (3.91)	1.63 (1.03)	18.73 (5.95)
Overall	9.03 (2.44)	9.11 (4.31)	2.82 (2.25)	20.97 (7.72)
Maximum	11	15	10	36

Results are presented through Mean (Standard Deviations)

Table 4 Mean and standard deviation of RCPM scores, according to the three-factorial clustering per baseline characteristics of the participants

	Factor III	**Factor I**	**Factor II**	**Total score**
General characteristics	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**	**Mean (SD)**
Age of the student (years)				
6-8	8.38 **(**2.63)	7.24 (3.85)	2.22 (1.47)	17.84 (6.56)
8-11	9.58 (2.16)	10.68 (4.05)	3.32 (2.64)	23.58 (7.69)
p-value	**0.007**	**<0.001**	**0.007**	**<0.001**
Age of the parents (years)				
≤40	9.02 (2.54)	9.27 (4.38)	2.71 (2.31)	21.00 (8.03)
>40	9.55 (1.77)	9.59 (3.91)	3.02 (2.25)	22.16 (6.58)
p-value	0.213	0.692	0.478	0.414
Sex Male	9.33 (2.15)	9.65 (3.90)	2.96 (2.31)	21.94 (6.94)
Female	8.84 (2.62)	8.77 (4.54)	2.73 (2.22)	20.33 (8.18)
p-value	0.275	0.274	0.581	0.264
Grade Grade 1	6.88 (3.05)	4.60 (3.35)	1.92 (1.08)	13.40 (6.16)
Grade 2	9.44 (1.46)	9.17 (2.77)	2.44 (1.29)	21.06 (4.40)
Grade 3	8.92 (2.68)	9.27 (3.12)	2.31 (1.99)	20.50 (6.05)
Grade 4	10.72 (0.59)	13.59 (1.68)	5.17 (2.62)	29.48 (4.01)
Grade 5	9.03 (2.45)	8.17 (4.22)	1.70 (1.36)	18.91 (6.44)
p-value	**<0.001**	**<0.001**	**<0.001**	**<0.001**
Marital status of the parents	9.29 (2.19)	9.47 (4.15)	2.93 (2.28)	
Married				21.69 (7.39)
Divorced/Widowed	8.91 (2.70)	9.09 (4.64)	2.55 (2.69)	20.54 (8.58)
p-value	0.595	0.777	0.602	0.632

Highest level of education				
Elementary school or less	9.29 (2.23)	8.43 (4.35)	3.07 (2.27)	20.79 (7.96)
High school	9.15 (2.38)	9.26 (3.92)	2.41 (2.15)	20.83 (6.91)
University or more	9.35 (2.16)	9.92 (4.41)	3.20 (2.40)	22.47 (7.89)
p-value	0.909	0.461	0.229	0.514
Economic situation				
Less than average	9.04 (2.49)	9.37 (4.29)	3.44 (2.33)	21.85 (7.70)
Average or more	9.36 (2.17)	9.55 (4.19)	2.71 (2.30)	21.62 (7.47)
p-value	0.517	0.844	0.154	0.893
Working status				
Both parents work	9.22 (2.59)	9.97 (4.63)	3.53 (2.59)	22.72 (8.73)
One parent works	9.37 (2.04)	9.58 (3.94)	2.61 (2.17)	21.57 (6.84)
Both parents do not work	8.67 (2.29)	6.56 (3.09)	2.33 (1.50)	17.56 (5.36)
p-value	0.670	0.083	0.118	0.178
Total number of children				
One child	8.47 (3.02)	9.20 (4.68)	2.07 (2.22)	19.73 (8.58)
Two children	9.45 (2.08)	9.33 (4.42)	3.14 (2.25)	21.92 (7.77)
Three children	9.54 (2.08)	10.31 (3.72)	2.86 (2.48)	22.71 (6.88)
Four children or more	8.64 (2.16)	7.73 (3.55)	2.91 (2.12)	19.27 (5.98)
p-value	0.302	0.329	0.477	0.414

Results are presented through Mean (Standard Deviations)

Table 5 Intellectual Capacity Classification Percentage as compared to students' age

	Age (years)					
Classification	6	7	8	9	10	11
Intellectually superior	1 (10.0%)	8 (38.1%)	9 (37.5%)	12 (46.2%)	13 (44.8%)	--
Definitely above-average in intellectual capacity	5 (50.0%)	10 (47.6%)	17 (70.8%)	17 (65.4%)	16 (55.2%)	1 (9.1%)
Greater than median	7 (70.0%)	14 (66.7%)	22 (91.7%)	19 (73.1%)	18 (62.1%)	4 (36.4%)
Intellectually average	3 (30.0%)	8 (38.1%)	8 (33.3%)	6 (23.1%)	7 (24.1%)	3 (27.3%)
Definitely below-average in intellectual capacity	3 (30.0%)	4 (19.0%)	1 (4.2%)	4 (15.4%)	7 (24.1%)	7 (63.6%)
Intellectually impaired	--	2 (9.5%)	--	1 (3.8%)	1 (3.4%)	4 (36.4%)
Total	10	21	24	26	29	11

Results are presented through Frequency (Percentage).

Table 4 displays the association between the scores (per factor and total score) and the participants' general characteristics. The score for simple pattern completion (factor III) was significantly higher among students aged 8-11 (9.58 over 11) than their younger peers (8.38; p=0.007). This score showed statistically significant variation depending on the student's grade, with the lowest score at grade 1 (6.88), which significantly increased at grade 2 (9.44) and attained its maximum value at grade 4 (10.72), then decreased again at grade 5 (9.03; p<0.001). Male students (9.33) had higher scores than females (8.84) with no statistical significance (p>0.05). The parent's characteristics did not statistically affect these scores (p>0.05), but it was noted that students with older (>40 years) and married parents and those with better economic situation (average or more) had higher scores for factor III. The score for factor I (discrete and continuous pattern completion) was significantly higher among older students (10.68) than their younger peers (7.24; p<0.001), and per increase of grade: maximum for grade 4 (13.59) and a significant decrease for participants in grade 5 (8.17; p<0.001). No statistically significant associations were noted with the other characteristics. Nevertheless, a lower score was noted among students with their parents not working (6.56; p=0.083). The closure and abstract reasoning score (factor II) was also significantly higher among those between 8 and 11 years compared to younger students (3.32 vs. 2.22; p=0.007). This score was significantly higher among students in grade 4 (5.17) compared to other grades (p<0.001). Moreover, students with a perceived economic situation below average (3.44) had higher scores than those with a better situation (2.71) with no statistical significance (p>0.05).

Students' intellectual Capacity was assessed according to their age and allocated into six categories (Table 5). Around 45.0% of students aged 9 and 10 were classified as intellectually superior, compared to none of those aged 11 and only 10.0% of those with six years. In contrast, for the intellectually impaired classification, students of 11 years were more frequent (36.4%), while age 9 (3.8%) and 10 (3.4%) reflected a comparable lower percentage. Among those aged 6 to 10, most students demonstrated a capacity greater than the median, above average, and intellectually superior. This was inversely applied to students aged 11 (36.4%). Thirty percent of 6 years old students were intellectually average or definitely below average, respectively. A third of those aged eight years were intellectually average, only 4.2% were definitely below average, and around 24% of those aged 10 were intellectually average or below average, respectively.

4. Discussion

This pilot study assessed children's reasoning ability using the RCPM test and identified those in need to develop supportive solutions accordingly. The complexity of solving each set of elements within each factor ranged from Factor III being the easiest and simplest reflected by the highest number of correct scores along all the age groups as early as the age of 6 since this factor relies on principal cognitive skills till Factor II being the lowest among all the age groups since it involved a more complex set of questions (Smirni, 2020). The age group selected in this study (6 to 11) was based on cognitive development during early childhood, with a capacity for logical thinking and differentiation between real and imaginary thinking (Gerosa et al., 2021). This general reasoning skill development is more apparent in age groups 61–72 months (5 to 6 years) than in younger age groups. This is due to a better ability to direct their logical interpretation based on surrounding factors in addition to their current knowledge, which is directly linked to brain maturation, working memory, and daily interactions (Prasanna et al., 2023).

The sample comprised more females than males, slightly different from the sex distribution in Lebanon (almost equal distribution between sexes) (Nasreddine et al., 2022). Male students had slightly higher scores than females with no statistically significant difference, in agreement with a recent study conducted in Vietnam in 2020 (Csapó, 2020). Nevertheless, previous research showed contradicting outcomes on the impact of sex on reasoning ability, wherein in a cross-sectional study, better reasoning ability was reported among females (Rubianti et al., 2022), while another concluded a higher creative thinking average score in males (Sun et al., 2022). At 11 years, students demonstrated lower scores in all the factors despite being the oldest age group in the study. This was translated into lower intellectual capacity compared to their younger peers. This scoring can be attributed to the increased complexity of the education material given at this age and their search for identity, independence, and autonomy. As children enter this age, they begin to develop their sense of identity and may challenge authority figures as a way of asserting their independence in addition to friends and peer groups' impact on their behavior (Pursey et al., 2021). Hormonal changes during puberty can lead to mood swings, which might contribute to defiant behavior and, as a result, may affect academic performance (Laube et al., 2020). Students of married parents had higher scores for specific factors than those with divorced/widowed parents. During childhood, the brain is highly reactive to external influences such as family, parent-child relationships, and socioeconomic factors, and any changes in such environment can interrupt the cognitive development of children (Wang, 2023). Interacting with peers and adults, discussing ideas, and engaging in collaborative activities can stimulate cognitive development. Supportive and nurturing parenting can contribute to a child's overall cognitive development, including fluid intelligence. Moreover, schools can integrate emotional education and coping skills into their curriculum to help students develop strategies for managing stress, anxiety, and other emotions related to their parent's divorce. Counseling services with trained professionals can offer guidance and

provide a safe space for students to express themselves. In this study, children with better socioeconomic status had significant scores, in agreement with a recent study concluding that social class directly influenced students' cognitive development (González et al., 2020). Both parents and school staff should maintain open lines of communication to ensure that the child's well-being is a priority. Sharing information about changes at home can help educators better understand and support the student's needs.

This study has limitations. The sample size is relatively small and only included students from a single center, which might affect its external validity and the extrapolation of the findings to other settings. It was conducted in a private school, which may assume that participants had higher socioeconomic status and, therefore, a possibility of support outside the school. The information provided by the parents might be provided by the parent who is not highly involved in the child's daily life. Nevertheless, to our knowledge, this is the first study conducted in Lebanon using a standardized tool. Further investigations will be performed on a more representative sample across Lebanon.

5. Conclusion

The current study showed that RCPM scores significantly depend on the child's age, where older age groups scored better than younger ones. There is a correlation between some parents' characteristics and RCPM scores, where the family-child relation, parents' education, and socioeconomic status affected the scores. There is no significant difference identified between males and females in scoring thus, sex has an impact on RCPM scoring. A larger sample size is required to validate the above study findings further and focus more on parents' characteristics to ensure the results.

Compliance with ethical standards

Acknowledgments

We would like to acknowledge the valuable guidance and support of the school's direction: Sr Hyam Sawiry (Superior of the School) and Nicole Choueïry (Responsible for the primary cycle). We also express gratitude for the collaboration of teachers, students, and their parents.

Disclosure of conflict of interest

The Authors declare that there is no conflict of interest.

Statement of ethical approval

The study protocol, questionnaire, and consent form were reviewed and approved by the scientific committee of the Lebanese University faculty of pharmacy (reference: 3/23/D). Written informed consent was obtained from every participant's parent/legal guardian.

Statement of informed consent

Informed consent was obtained from all individual participants included in the study.

Fundings

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

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