ISSN: 2986-9994

The Grant Medical Journals®

June, 2017; 02(05): 104-115 psy/17/1721/gmj

Psychiatry
Original Research Paper

Crystallized and Fluid Intelligence of Adolescents and Adults with Intellectual Disability and with Typical Development: Impaired, Stable or Compensatory Trajectories?

Irit Chen[1], Hefziba Lifshitz[2] & Eli Vakil[3].
[1]Efrata College of Education, Jerusalem, Israel
[2]Special Education Department, Machado Chair for Research on Cognitive Modifiability and Human Development, School of Education, Bar-Ilan University, Israel
[3]Department of Psychology and Leslie and Susan Gonda (Goldschmied) Multidisciplinary Brain Research Center, Bar-Ilan University, Ramat-Gan, Israel
*****Corresponding author(s): Hefziba Lifshitz, Special Education Department, Machado Chair for Research on Cognitive Modifiability and Human Development, School of Education, Bar-Ilan University, Israel
Email: hefziba@013net.net

Published: 2017.06.29.

ABSTRACT

Three possible cognitive trajectories in the population with ID (Fisher & Zeaman, 1970; Lifshitz –Vahav, 2015) through the life span compared to the cognitive trajectory of the Typical developed (TD) population (Kauffman, 2001; Wechsler, 1981) were proposed. The "Impaired", "stable" and "Continuous" Trajectories. This study's goal was to examine Crystallized and fluid intelligence trajectories in individuals with non-specific ID (IQ=50-70) compared to individuals with typical development in four age cohorts: young adolescence (10-16), older adolescence (17-21), young adulthood (23-29) and adults (31-40). Method: Participants were individuals with mild to moderate NSID (N=102, IQ=50-70), who were compared to individuals with TD (N=102, IQ=85-115) in four age groups (10-16, 17-21, 23-29, 31-40). Crystalized Intelligence was examined by Vocabulary, Similarities (Wechsler battery, 2001, 2010), and Semantic fluency (Kavé, 2005). Fluid intelligence was examined by the Raven Matrices (1983), Phonemic fluency (Kavé, 2005), and Block design (Wechsler, 2001, 2010). Results: Vocabulary and Similarities revealed a parallel Continuous trajectory from 17 to 40. Semantic fluency revealed a parallel continuous trajectory from 10 to 17-21. Phonemic fluency and the Raven peaked at the 17-18 among the TD population and at the 19-21 in the ID population. Block design revealed in the TD group indicate a decline from older adolescents to adulthood (17-40) whereas ID group revealed Continuous trajectory from 21 to 40. Conclusions: Our findings support the Compensation Age Theory (Lifshitz-Vahav, 2015) regarding the contribution of chronological age to the cognitive ability of individuals with ID. Furthermore, adults with ID can benefit not only from mediated learning experience but also from direct exposure to the stimulus.

Keywords: Crystallized and Fluid intelligence; individuals with ID; impaired, stable, continuous trajectories.

INTRODUCTION

The main goal of this study was to examine crystallized and fluid intelligence trajectories in individuals with non-specific ID (IQ = 50-70) compared to individuals with typical development (TD) in four age cohorts: Young adolescents (10-16), older adolescents (17-21), young adults (23-29) and adults (31-40). The uniqueness of this holistic study lies in the following: a) This is the first cross-sectional examination of cognitive trajectories among individuals with ID from adolescence to adulthood compared to individuals with TD in the same age cohort; b) Simultaneous examination of crystallized intelligence and fluid intelligence; c) Examination of the above domains in light of three possible trajectories of intelligence and cognitive ability among individuals with ID: Impaired, Stable and Compensatory Trajectories (Fisher & Zeaman, 1970; Lifshitz-Vahav, 2015).

THEORETICAL BACKGROUND

Three possible cognitive trajectories of growth and decline throughout the life span have been proposed for the population with ID compared to the general population (Fisher & Zeaman, 1970; Lifshitz-Vahav, 2015). These trajectories are based on traditional theories of intelligence in the general population (Kauffman, 2001; Wechsler, 1981), according to which intellectual functioning increases linearly up to the age of 20, after which there is an asymptote (stability), with a decline beginning around age 60. The proposed cognitive trajectories in the population with ID differ from each other in (a) the age at which intelligence reaches its peak; (b) the length of the stability period; (c) the onset age for the decline.

The Impaired Trajectory predicts that individuals with ID will exhibit restriction in the development of intelligence before their 20's. Thereafter, they will exhibit stability their mid-thirties, after which they will exhibit decline. The impaired trajectory is based on the Cognitive Reserve Theory (Katzman, 1993) which posits that normally occurring individual differences in the way people, process tasks might provide a differential reserve against brain pathology or age-related changes. Individual differences may result from innate characteristics (e.g., intelligence), or may be modulated by life events such as educational or occupational experiences or leisure activities (Scarmeas & Stern, 2003). Individuals with ID possess less cognitive reserve than their peers with TD, by definition (Zigman et al., 2004), due to lower intelligence and educational achievements, lower occupational statuses, and fewer opportunities for intellectually stimulating leisure activities.

The Stable (parallel) Trajectory predicts that the intelligence of individuals with ID will reach its peak in their twenties, after which there will be an asymptote and the onset of decline is at age 60. The difference between the two groups is expressed in the baseline IQ level, which is two standard deviations below the norm in the population with ID. This model emerged from aging studies that examined cognitive change among adults with ID (Facon, 2008; Zigman et al., 2004). If people with ID have reduced cognitive reserve compared with their peers with TD, by definition, then they would be expected to be at greater risk for dementia of the Alzheimer type (DAT) with increasing age than the general population (Snowdon, Greiner, & Markesbery, 2000). However, several studies (Merrick, 2010; Zigman et al., 2004) found an equivalent or even lower risk of dementia among adults with non-specific ID. The above authors reached the conclusion that the Cognitive Reserve Theory is not applicable to the population with ID. On the contrary, studies (Devenny, Hill, Patxot, Silverman, & Wisniewski, 1992; Facon, 2008) found the similar evolution of intelligence among adults with ID and adults with TD.

The Compensatory Trajectory postulates that while intelligence in the general population grows linearly up to the age of 20, individuals with ID will be compensated in later years due to the developmental delays they experience in their early years (Fisher & Zeaman, 1970). In a series of studies, Lifshitz and her colleagues found that adults with ID (aged 20-70; IQ 40-70) can benefit from focusing cognitive interventions aimed at ameliorating specific cognitive skills that are prone to decline with age, such as verbal abstraction skills, orientation in time and space (Lifshitz & Rand, 1999; Lifshitz & Tzuriel, 2004) and analogical reasoning (Lifshitz, Tzuriel, Weiss, & Tzemach, 2011). Based on these and other studies, Lifshitz-Vahav (2015) developed the Compensation Age Theory (CAT). This theory postulates that chronological age plays an important role in determining the cognitive ability of individuals with ID beyond their mental age, but contrary to prior assumptions (Cuppos, 2013) in a positive effect. Furthermore, the CAT claims that in later years there is compensation for the developmental delays experienced by individuals with ID in their early years and that their intelligence and cognitive performance might continue to grow until their 50s, and that they can be modified even at an advanced age. Maturity and cumulative life experience help adults with ID acquire cognitive skills that were previously absent from their behavioral repertoire.

The Compensation Age Theory is anchored in the theory of Structural Cognitive Modifiability and the Active Modifying approach (Feuerstein & Rand, 1974; Feuerstein, 2003). These theories claim that the human organism is a system open to its environment and accessible to change, even in the presence of three formidable obstacles usually believed to prevent change: (a) age, (b) etiology, (c) severity of limitation. One might argue that individuals with ID are exposed to lower cognitive reserve due to their lower level of intelligence, fewer opportunities for cognitive education and cognitive leisure activities. Our argument is that cognitive reserve in individuals with ID should be examined within the population with ID itself, and not compared to the general population. There are individual differences within the population with ID in task processing, according to intelligence level and life events.

CRYSTALLIZED AND FLUID INTELLIGENCE

McGrew (2009) re-defined the Horn-Cattell model (1967) of crystallized and fluid intelligence. Crystallized intelligence is defined as “a person’s acquired knowledge of the language, information and concepts of a specific culture’’ (p. 5). Fluid intelligence is defined as “the use of deliberate and controlled mental operations to solve novel problems that cannot be performed automatically” (p. 5). It is associated with the frontal executive function (Kauffman, 2001), working memory, analogies and metaphor understanding. In the general population, fluid intelligence is a “vulnerable” ability, peaking in the early 20s and then declining (Kauffman, 2001). The crystallized and fluid tests used in this study can be regarded as markers for these constructs. We will first review studies on the two types of intelligence during adolescence and adulthood.

DEVELOPMENT OF CRYSTALLIZED AND FLUID INTELLIGENCE

Adolescents and adults with TD: Studies carried out among individuals with TD (for example, Farkas & Beron, 2004; Fry & Hale, 2000; Wassenberg, Hurks, Hendriksen, Feron, Meijs, Vles, & Jolles, 2008) showed a non-linear increase in crystallized and fluid intelligence during childhood and adolescence. The improvement is rapid during childhood and moderates during adolescence. Aarnoutse, Van Leeuwe, Voeten and Oud (2001) followed the development of reading and language skills among children for six years and found an increase in vocabulary, spelling and reading comprehension. However, a decrease in the rate of development was observed with the increase in age. Kavé, Kigel and Kochva (2008) found an increase in Hebrew semantic and phonetic fluency tasks from childhood (age 8) to the end of adolescence (age 16-17). No difference was found between the adolescents and the adults.

Using the WAIS Verbal and Performance Scale (Wechsler, 1997), Kauffman (2001) found that crystallized intelligence peaked at ages 45-54 and the onset of decline was at ages 80-90. Fluid intelligence reached its peak at ages 20-24. Thereafter, there was a decline of five points every decade (0.5 points every year). The same findings were found in cross-sectional and longitudinal studies. These results support the above-mentioned Horn-Cattell hypothesis (1967).

In the Seattle Longitudinal Study, Schaie, Willis and Caskie (2004) charted the course of selected psychometric abilities (Thurstone, 1938) from young adulthood through old age. Their findings support the claim that fluid abilities tend to decline earlier, but not before the age of 50, whereas crystallized abilities show a steeper decrement in the late 70s

(Schaie et al., 2004). Schaie et al. postulated that age changes in perceptual speed begin in young adulthood and show a linear decrement. They also concluded that significant practical, age-dependent decrement before the early 60s can be dismissed. The decrement begins in the mid-60s and becomes substantial for most individuals by their early 80s.

Viskontas, Morrison, Holyoak, Hummel and Knowlton (2004) examined the ability of young adults (20-40), middle-aged (40-60), and older adults (60+) to integrate multiple relationships. The older group performed much less accurately than both younger groups. However, the performance of the middle-aged people resembled that of the young people in terms of accuracy, and that of older people in terms of response time. The authors suggested that the decrease in the effectiveness of attention and inhibition in working memory with age may explain the performance changes observed in the analogy task. Thus, there is agreement that not all measures of fluid intelligence are sensitive to age.

Adolescents and adults with ID: There is a dearth of research on crystallized and fluid intelligence in the population with ID in general, and particularly at advanced ages. In a six-year longitudinal study, Devenny et al. (1996) found that adults with non-specific ID improved their Digit Span, Block Design, and coding scores. The improvement in the younger group (<40) was greater than in the older group (>49). Contrary to the trends in the general population, Kittler, Krinsky-McHale and Devenny (2004) found a decline over a 7-year period in the Wechsler Intelligence Scale for Children-Revised (WISC-R) (1991) among adults with ID. Facon (2008) supported the parallel trajectory model using WAIS-R results of adults with and without ID aged 20 to 54 years. Hierarchical regression among the two groups showed the similar evolution of scores with increasing age for verbal and performance scales. Facon's study focused on adulthood, whereas our study examined intelligence trajectories of individuals with and without ID from young adolescence to adulthood.

The above studies suffer from several limitations: (a) except for one (Facon, 2008), all focused either on a population with TD or with ID, without a comparison between the two populations; (b) they focused on specific skills such as memory or intelligence, thus presenting partial data on the cognitive trajectory in the two populations; (c) none examined the trajectory from adolescence to adulthood. Our study attempted to overcome these limitations.

Our study is cross-sectional. The efficacy of cross-sectional versus longitudinal assessment was raised by several researchers. Kaufman (2001) found the same findings for crystallized and fluid trajectories with increasing age in cross-sectional and longitudinal studies. Salthouse (2009) also examined the efficacy of both methods when measuring cognitive change with increasing age in the general population. Cross-sectional studies may suffer from cohort effects, which are associated with the social and cultural environment. Longitudinal studies may suffer from a "retest effect". According to Salthouse, "only variables that exhibiting negative age-related differences in cross-sectional comparisons, are directly relevant to using the longitudinal method" (page. 513).

This is a pioneering study that examined the cognitive trajectory from adolescence to adulthood in a population with ID versus peers with TD in same age cohorts. The ideal method is to examine the cognitive trajectory in a longitudinal study. However, other researchers used cross-sectional studies for examining cognitive trajectories in this population (Facon, 2008), since it is difficult to collect longitudinal data for this population in adulthood. Our hope is that the data from this study will serve as a basis for conducting longitudinal research in the future.

The main goals of this cross-sectional comparison were: (a) to examine the cognitive trajectory of participants with ID from adolescence (10-16; 17-21) to adulthood (23-40) in light of three possible trajectories: impaired, parallel or compensatory; (b) to compare the performance of participants with ID to their peers with TD in the same age cohort; (c) to examine the cognitive trajectory by monitoring a wide range of neurocognitive domains: crystallized and fluid intelligence.

Crystallized intelligence hypotheses

Participants with TD: An increase in performance will be found from adolescence to adulthood, i.e. scores at ages 23-40 will be higher than at ages 17-21. Scores in Semantic fluency skills will be higher at ages 17-40 than at ages 10-16.

Participants with ID: Based on the Compensation Age Theory (Lifshitz-Vahav, 2015) and the results of intervention studies on adolescents and adults with ID, we predict that a parallel development trajectory will be found, i.e. the gap in performance between participants with ID and participants with TD will be similar in all ages.

Fluid intelligence hypotheses

Participants with TD: There will be an increase in performance from young adolescence to older adolescence, and a decrease from older adolescences to adulthood, i.e. scores at ages 17-40 will be higher than at ages 10-16 and scores at ages 31-40 will be lower than at ages 17-21. Participants with ID: Due to mixed results for fluid intelligence in the population with ID, we preferred to pose a question: Will fluid intelligence show parallel performance between participants with TD and with ID?

METHOD

Participants

The sample included 204 participants, 50% with non-specific ID and 50% with TD divided into four age cohorts: young adolescents aged 10-16; older adolescents aged 17-21; young adults aged 23-29; middle-age adults aged 31-40 (Selfhout, Branje, & Meeus, 2009; Moore, Strauss, Herman, & Donatucci, 2003).

Participants with ID: The participants with ID included adolescents (n = 58; age = 10-21) who were recruited from special needs schools and adults (n = 44; age = 23-40) who were recruited from residential and employment settings. Inclusion criteria were: (a) chronological age: 10-40; (b) mild and moderate ID, i.e. IQ between 50-70. The reason for our choosing this range of IQ is that participants with lower levels of ID cannot be assessed by the WAIS (Wechsler, 2001); (c) Employment in the community or a vocational workshop, living with the family/community apartment/hostel; (d) considered healthy from a biological perspective, and without sensory impairments such as hearing or visual impairment; (e) without behavioral problems. One-way ANOVAs performed in the three adult age cohorts (ages 17-40) did not demonstrate differences in the general IQ between the groups, $F(2, 66) = 1.65$, $p > .05$, $\eta 2 = .05$.

Participants with TD: The participants with TD included adolescents (N = 58; age = 10-21) who were recruited from regular schools and adults (N = 44; age = 23-40) who were merchants and professionals. Inclusion criteria included: (a) chronological age: 10-40; (b) IQ between 85-115. The reason for choosing this range of IQ is that this is the average range of IQ in the general population; (c) considered healthy from a biological perspective and without sensory impairments. These participants were matched to participants with ID based on gender and chronological age. One-way ANOVAs (3x1) performed in the three adult age cohorts (ages 17-40) did not demonstrate differences in the general IQ between the groups, $F(2, 66) = 2.23$, $p > .05$, $\eta 2 = .06$.

IQ calculation: For participants with ID aged 17-40 and with TD aged 10-40, calculation of the IQ was performed according to three subscales of the Wechsler (ages 10-16: WISC-IVHEB, 2010; ages 17-40: WAIS-IIIHEB, 2001): Vocabulary, Similarities and Block Design. These three tests are indications of the general intelligence, according to the WASI™ (Wechsler Abbreviated Intelligence Scale, Wechsler, 1999). This procedure was used in a population with TD (Canivez, Konold, Collins, & Wilson, 2009; Sattler, 1992) and in a population with ID (Gawrylowicz, Gabbert, Carson, Lindsay, & Hancock, 2012).

The IQ of participants with ID aged 10-16: In this population, we tried to use the Wechsler test for Children (WISC-IVHEB, 2010). This Hebrew version of the test is considered difficult among the population with ID (Israeli Psychological Service, 2013). As a result, the scores of the group with ID in our study were low and it was difficult to produce IQ scores. Their cognitive level was therefore measured by the Raven Standard Progressive Matrices (Raven, Raven, & Court, 1998) which is commonly used for testing the cognitive level in the population with ID (Jansen, De Lange, & Van der Molen, 2013). The mean scores of participants with ID aged 10-16 was M = 17.91, SD = 3.07, which is equal to IQ = 50-70. Table 1 presents the distribution of participants with ID and TD according to age and IQ level.

Assessment tools

The Crystallized battery included the Vocabulary and Similarities subtest (ages 10-16: WISC-IVHEB, 2010; ages 17-40: WAIS-IIIHEB, 2001), and the Semantic fluency test (Kavé, 2005). Vocabulary measures word knowledge, verbal concept formation, and fund of knowledge (WISC-IVHEB: 37 items, scores range 0-70; WAIS-IIIHEB: 33 items, scores range 0-66). Similarities assess abstract reasoning and the power of conceptualization for dissimilar objects (WISC-IVHEB: 33 items, scores range 0- 44; WAIS-IIIHEB: 19 items, score range 0-33). Raw scores were used in both tests in order to test the influence of age on performance. Semantic Fluency examines verbal knowledge, retrieval ability, and lexical production. Participants provide as many words as possible in each of three categories (fruits and vegetables/animals/vehicles) within 60 seconds. The score is the sum of the words generated for all three categories.

The Fluid battery included the Phonemic Fluency test (Kavé, 2005), Raven Matrices tests (Raven et al., 1998) and the Block Design subtest (ages 10-16: WISC-IVHEB, 2010; ages 17-40: WAIS-IIIHEB, 2001). Phonemic Fluency examines executive control functions. Participants provide as many words as possible beginning with each of the three letters (in Hebrew /b/, /g/, /sh/) within 60 seconds. The score is the sum of the words generated for all three letters. The Colored and the Standard Progressive Matrices assess the ability to form comparisons, deduce relationships, correlates, and reason by analogy.

The Colored Matrices include 3 sets: A, AB, B and the Standard Matrices include 5 sets: A, B, C, D, E (A, B is identical to the Colored Matrices except for the color). Each set contains 12 items. Participants with ID and young adolescents (age 10-16) with TD solved the Colored Matrices sets and C, D, E sets of the Standard Matrices. Correct answers received 1 point. Scores were the sum of the raw scores (range 0-72). Block Design measures the ability to analyze and synthesizes abstract visual stimuli, nonverbal concept formation, visual perception and organization, simultaneous processing and visual-motor coordination (WISC-IVHEB: 13 items, scores range 0-68; WAIS-IIIHEB: 14 items, scores range 0-68). Raw scores were used to test the influence of age on performance.

Procedure

Consent for the participation of participants with TD (ages 10-18) and with ID was obtained from the participants' parents/guardians. Authorizations were obtained from the University Ethics Committee, the Division of Individuals with ID in the Ministry of Welfare and in the Ministry of Education. The study's aim and procedure were explained to all participants, who signed an adapted informed consent form for the participation of individuals with ID in scientific research. The battery of tests was administered individually, in schools, colleges or in residential and employment settings. Administration of the tests to participants with ID was conducted in sessions of one hour to an hour and a half or in two sessions. The participants were rewarded with payment or a gift, depending on their age.

RESULTS

The independent variables were the study populations (ID and TD) and age cohorts (10-16, 17-21, 23-29, 31-40). The dependent variables were the Crystallized and the fluid intelligence measures. With regards to the Wechsler subtests, as a result of the different version of the intelligence test for young adolescents (10-16, WISC-IVHEB, Wechsler 2010) compared to the other groups (WAIS-IIIHEB, Wechsler 2001), the differences in scores between the age 10-16 cohort and the other age cohorts was examined by comparing the effect size of the four age cohorts. This method is recommended in studies conducted on intellectual and developmental disabilities when the samples are not equal (Kover & Atwood, 2013).

Crystallized intelligence

A two-way (2 X 3) MANOVA (study populations x age cohorts) was performed in order to examine whether differences in Vocabulary and Similarities would be found between the study populations and three age cohorts. A significant main effect was found for study populations, $F(2, 131) = 1192.31$, $p < .001$, $\eta 2 = .95$, and for age cohorts (Table 2 and Figures 1 and 2).

Differences in study populations: A one-way ANOVA performed for examining the differences between the study populations, for each of the dependent variables separately, indicated that the performance of the participants with TD is higher than that of participants with ID in Vocabulary, $F(1, 132) = 2098.11$, $p < .001$, $\eta 2 = .94$, and in Similarities, $F(1, 132) = 1079.24$, $p < .001$, $\eta 2 = .89$.

Differences between age cohorts: A one-way ANOVA for examining the differences between the age cohorts, conducted for each of the dependent variables separately, indicated significant differences in age cohorts in Vocabulary, $F(2, 132) = 8.30$, $p < .001$, $\eta 2 = .11$, and in Similarities, $F(2, 132) = 4.09$, $p < .05$, $\eta 2 = .06$. Scheffe post hoc analysis indicated significant differences in scores of the 23-29 and 31-40 age cohorts compared to the 17-21 cohort in Vocabulary and Similarities, whereas no significant population x age cohorts difference was found between the 23-29 and 31-40 age cohorts. The effect size between the four age cohorts indicated a similar size, as follows: Vocabulary, $\eta 2 = .93$ (ages 10-16), $\eta 2 = .97$ (ages 17-21), $\eta 2 = .93$ (ages 23-29-19), $\eta 2 = .91$ (ages 31-40). Similarities, $\eta 2 = .89$ (ages 10-16), $\eta 2 = .90$ (ages 17-21), $\eta 2 = .87$(ages 23-29), $\eta 2 = .90$ (ages 31-40). Similar strength of differences between the study populations in the different age cohorts indicates that development in these measures is similar in the two study populations.

Semantic fluency (Kavé, 2005), all age cohorts. A two-way ANOVA (2 X 4, study populations x age cohorts) indicated a significant main effect for study populations, $F(1, 196) = 622.49$, $p < .001$, $\eta 2 = .76$. The scores of the participants with TD were higher than those of participants with ID. A significant main effect was also found for age cohorts, $F(3, 196) = 11.92$, $p < .001$, $\eta 2 = .15$. Scheffe post hoc analysis yielded higher scores for the 17-21, 23-29 and 31-40 age cohorts compared to the 10-16 cohort. No significant interaction of study populations x age cohorts was found (Table 2 and Fig. 3). The absence of an interaction between study populations and age cohorts in the Semantic Fluency measure indicates a parallel development trajectory.

Fluid intelligence

Phonemic Fluency (Kavé, 2005), all ages. A two-way ANOVA (2 X 4, study populations x age cohorts) was performed in order to test whether differences exist in the Phonemic Fluency test with reference to the study populations. A main effect was found for study populations, $F(1, 196) = 618.76$, $p < .001$, $\eta 2 = .76$, where the performance of participants with TD was higher than that of participants with ID. A main effect was also found with reference to the age cohort, $F(3, 196) = 19.00$, $p < .001$, $\eta 2 = .22$. Scheffe post hoc analysis indicated that the achievements of participants in the 17-21, 23-29 and 31-40 age cohorts are significantly higher than the achievements of participants in the 10-16 age cohort. A significant study populations x age cohorts interaction was found, $F(3, 196) = 6.82$, $p < .001$, $\eta 2 = .09$.

Simple effect analyses were performed in order to test the source of the interaction. Differences in performance in the Phonemic Fluency test were found according to age cohorts, both among participants with ID, $F(3, 98) = 5.07$, $p < .01$, $\eta 2 = .13$, and among participants with TD, $F(3, 98) = 14.53$, $p < .001$, $\eta 2 = .31$. Scheffe post hoc analyses indicated that the performance of participants with TD in the 17-21 ($p < .001$), 23-29 ($p < .001$) and 31-40 ($p < .001$) age cohorts are significantly higher than those of participants in the 10-16 age cohort, and that there is no difference between the three older age cohorts. Among participants with ID, performance of participants in the 23-29 ($p < .05$) and 31-40 ($p < .05$) Age cohorts was significantly higher than among participants in the 10-16 age cohort, and no difference was found in the performance of participants in the 10-16 and 17-21 age cohorts and the performance in the three older age cohorts (Table 2 and Fig. 4). This finding is compatible with those of the Raven indicating a continuous trajectory among participants with ID.

Raven (CPM, SPM, Raven 1956, 1958) for all ages. A two-way ANOVA (2 X 4, study populations x age cohorts) indicated a significant main effect for study populations, $F(1, 196) = 5023.64$, $p < .001$, $\eta 2 =$

.96, where the scores of participants with TD were higher than those of participants with ID. A main effect was also found for age cohorts, $F(3, 196) = 26.91$, $p < .001$, $\eta 2 = .29$. Scheffe post hoc analysis indicated that the performance of participants in the 17-21, 23-29 and 31-40 age cohorts was significantly higher than that of participants in the 10-16 age cohorts. A significant interaction of study populations x age cohorts was also found, $F(3, 196) = 5.66$, $p < .001$, $\eta 2 = .08$.

Simple effect analyses were performed in order to find the source of the interaction between the age cohorts in each of the study populations. Significant differences between age cohorts were found for participants with ID, $F(3, 98) = 5.38$, $p < .01$, $\eta^2 = .14$, and for participants with TD, $F(3, 98) = 25.82$, $p < .001$, $\eta^2 = .44$. Scheffe post hoc analysis indicated that the performance of participants with TD in the 17-21 ($p < .001$), 23-29 ($p < .001$) and 31-40 ($p < .001$) age cohorts was significantly higher than that of the participants in the 10-16 age cohort, with no difference in performance between the three older cohorts. Among participants with ID, the performance of participants in the 23-29 ($p < .05$) and 31-40 ($p < .01$) age cohorts was significantly higher than that of participants in the 10-16 age cohort, with no difference between the 10-16 and 17-21 age cohorts and between the 23-29 and 31-40 age cohorts (Table 2 and Fig. 5). This finding indicates a continuous development trajectory in both populations: Older adolescents and adults with TD exhibit higher performance than younger adolescents (10-16), whereas among the participants with ID, only the adult age cohorts (23 and older) exhibit higher performance than the younger adolescents.

Block Design (WAIS-IIIHEB, 2001), adults. A two-way ANOVA (2 X 3, study populations x age cohorts) indicated a significant main effect for study populations, $F(1, 132) = 954.03$, $p < .001$, $\eta 2 = .88$: scores of participants with TD were higher than those of participants with ID. No main effect for age cohorts was found. However, a significant study populations x age cohort interaction was found, $F(2, 132) = 5.60$, $p < .01$, $\eta 2 = .08$.

Simple effect analyses were carried out in order to find the source of the interaction, for comparison between age cohorts in each of the study populations. Differences in Block Design performance were found, according to age cohorts among participants with ID, $F(2, 66) = 4.45$, $p < .05$, $\eta^2 = .12$. Scheffe post hoc analysis indicated significantly higher ($p < .05$) performance of participants with ID in the 31-40 age cohort compared to the 17-21 age cohort. No differences between age cohorts were found among participants with TD (Table 2 and Fig. 6). This finding indicates a stable trajectory among participants with a TD and a continuous trajectory among participants with ID.

Block Design (WISC-IVHEB, 2010), young age cohort (10-16): A one-way ANOVA (study populations x age cohorts) indicated a significant main effect for study populations, $F (1, 64) = 722.14$, $p < .001$, $\eta 2 = .92$: Scores of participants with TD ($M = 43.73$, $SD = 6.49$) were higher than those of participants with ID ($M = 6.21$, $SD = 4.71$).
The effect size was also calculated, in order to examine differences between age 10-16 and the other age cohorts. The differences in the effect size between the groups with TD and with ID was greater for the 10-16 age cohorts ($\eta^2 = .92$) than the effect size among the 31-40 age cohorts ($\eta^2 = .79$). Thus, the development pattern among the participants with TD is different from that of the participants with ID, where the gap in performance decreases with age.

DISCUSSION

Trajectories of crystallized and fluid intelligence among individuals with ID compared with individuals with TD will be at the core of the discussion.

Trajectories of crystallized and fluid intelligence

Crystallized intelligence was examined by Vocabulary, Similarities (WISC-IVHEB, Wechsler, 2010; WAIS-IIIHEB, Wechsler, 2001) and Semantic Fluency (Kavé, 2005). The research hypotheses were supported for both study populations. The population with TD exhibited higher scores in adulthood (23-40 age cohorts) compared to older adolescents in both Vocabulary and Similarities. This pattern is in accordance with studies (Hurks et al., 2010; Kaufman, 2001; McArdle et al., 2009; Wassenberg et al., 2008) that demonstrated an increase in crystallized intelligence in the population with TD even at an advanced age. Participants with ID exhibited higher scores in Vocabulary and Similarities in the 23-40 than in the 17-21 age cohorts. As for Semantic Fluency, in both groups, older adolescents exhibited a similar level of semantic fluency as adults. Furthermore, scores of older adolescents and adults were higher compared to younger adolescents. According to Kavé et al. (2008), adolescents aged 16-17 exhibit a similar level of semantic fluency as adults since towards the end of adolescence effective retrieval strategies have matured and the vocabulary necessary for successful performance of this task already exists.

McGrew (2009) defined crystallized intelligence as “the knowledge of the culture that is incorporated by individuals through a process of acculturation". Based on this notion, the higher scores of adults compared to adolescents in the population with TD is not surprising. However, our study is the first to demonstrate the higher crystallized performance of adults with ID compared to younger or older adolescents with ID. Facon (2008) indicated an increase in crystallized ability among adults with ID. However, Facon focused on the ages of 20-54. Our study covered the adolescence period (age 10-21) and adulthood (age 23-40) and revealed the higher performance of adults with ID compared to adolescents with ID.

Fluid intelligence was examined in our study by Phonemic Fluency (Kavé, 2005), the Raven (CPM – Raven, 1956; SPM – Raven, 1958) and Block Design (WAIS-IIIHEB, Wechsler, 2001; WISC-IVHEB, Wechsler, 2010). Our hypothesis regarding the population with TD was partially supported: Older adolescents and adults with TD exhibited higher performance in Phonemic Fluency and the Raven SPM compared to younger adolescents. Our hypothesis of lower performance of the 31-40 age cohort was not supported. This finding confirms others (Salthouse, 2004; Verhaeghen & Salthouse, 1997; Viskontas, Morrison, Holyoak, Hummel, & Knowlton, 2004) which demonstrate stability in complex cognition, such as analogical reasoning, at these ages. Decrement was shown in these studies in older ages, such as 50+.

One of the intriguing findings is that participants with ID exhibited a parallel trajectory to the participants with TD in Phonemic Fluency and in the Raven test. That is, the performance of the adults was higher as compared to younger adolescents. However, among the participants with TD, the performance of older adolescents and adults was higher than younger adolescents (10-16), among the participants with ID, only the adult age cohorts (23 and older) exhibited higher performance than the younger adolescents.

Since the findings in the Raven and Phonemic Fluency measures were similar, we were eager to find the peak age of the development in the two populations. For this purpose, we divided the 17-21 age cohort into a 17-18 and a 19-21 age cohort and compared them to the scores in each of the other age cohorts (10-16, 23-29, 31-40). The findings indicate a different pattern for the two study populations: Among participants with TD, the Raven test and Phonemic Fluency reached their peak at ages 17-18, whereas among participants with ID, Raven and Phonemic Fluency reached their peak at ages 19-21. Thus, there is a gap of 2-4 years at the peak of development of these two tests between the populations with TD and with ID.

The second intriguing finding relates to Block Design, which revealed a different trajectory among the populations with TD and with ID. Contrary to our hypothesis for the population with TD, the trend of Block Design shows stability with slight decrement from age 17-21 to 23-29 (the differences between the two age cohorts were not significant) and the performance at age 31-40 was similar to that of (with slight decrement) the younger adults with TD (age 23-29). In contradistinction, participants with ID exhibited a continuous trajectory. Their performance in Block Design reached its peak at a later age than among those with TD: Performance of the 31-40 age cohort was significantly higher than that of the 17-21 age cohort. Our findings indicate that the development of the fluid intelligence, ability of individuals with ID differs from that of individuals with TD not only in the basic ability level but in the development trajectory.

In the general population, it is evident that brain maturation, including frontal lobes and prefrontal cortex, reach their peak in late adolescence. Epstein (1974, 1986) and McCall (1988; McCall, Meyers, Hartman, & Roche, 1983) presented discrepant findings regarding the presence of stages in the brain and cognitive maturation, as described in the Piagetian theory. Quantitative electroencephalograms (Hudspeth & Pribram, 1990) using Piagetian tasks from childhood to adulthood provide stronger support for the conclusion that regional brain maturation exhibits growth spurts according to Piaget's (1971) stages. The formal and dialectic stages reach their peak around late adolescence (around age 21), after which they exhibit plateaus.

The maturation process in the fluid intelligence measures among adolescents with ID is apparently slower than among those with TD and their fluid intelligence ability, therefore reaches its peak at a later age. Caution should be exercised regarding this conclusion. fMRI and EEG studies in the population with ID should be conducted in order to support this assertion. These findings support the assertion of the Compensation Age Theory (Lifshitz-Vahav, 2015) mentioned earlier, according to which intelligence and cognitive performance of individuals with ID might continue to grow until their 50s. The positive effect of chronological age stems from the fact that maturity and cumulative life experience help adults with ID acquire cognitive skills that were previously absent from their behavioral repertoire.

Our findings raise a question regarding the nature of ID according to the DSM-5 (American Psychiatric Association, 2013). According to the DSM-5, the deficits in intellectual functioning of individuals with ID are expressed, among others, by "reasoning, problem-solving, planning, abstract thinking, judgment, academic learning and learning from experience" (p. 33). The relevant criterion for the present study is the ability of persons with ID to learn from experience. Lifshitz and her colleagues found that adults with ID (age 20-70; IQ 40-70) can benefit from cognitive interventions, even at an advanced age (Lifshitz & Rand, 1999; Lifshitz, Tzuriel, Weiss, & Tzemach, 2011). There is a myth that individuals with ID exhibit difficulty in benefiting from direct learning exposure. Mediated learning occurs (Feuerstein, 2003; Tzuriel, 2013) when the environment is interpreted for an individual by a mediator who actively structures meaningful components of that environment, as well as of past and future experiences. Direct exposure is characterized by unmediated encounters with stimuli in the environment. Our participants exhibited higher scores in the 31-40 age cohort compared to the 17-21 age cohort (with no intervention). That is, individuals with ID can benefit not only from mediated learning but also from indirect learning, mainly in adulthood.

According to the Compensation Age Theory (Lifshitz-Vahav, 2015), individuals with ID exhibit cognitive reserves, which enable them to develop and sprout at least into their forties, despite their lower level of intelligence. Following the Cognitive Activity Theory (Wilson et al., 2002), Lifshitz, Shnizer, and Mashal (2015) examined the impact of participation in leisure and cognitively-stimulating activities in the short-term cognitive performance of adults (age 23-50) with non-specific ID and with Down syndrome. Hierarchal regressions indicated that participation in cognitively stimulating activities contributed significantly to the explained variance of most of the crystallized and fluid tests. The activities in the above study require a basic level of information processing such as watching TV, writing, reading, playing games, using the technological devices (i.e., tablet, laptop, etc.). In our study, we did not examine the frequency at which our participants engaged in leisure and cognitively-stimulating activities. As far as we know, they live in community residences which offer them a large choice of leisure activities. The accumulation of these activities may be expressed by the continuous trajectory that was found in our study.

CONCLUSIONS

Our goal was to examine trajectories of crystallized and fluid intelligence of participants with ID compared to those with TD in four periods of the life cycle: young adolescence (age 10-16), older adolescents (age 17-21), young adulthood (age 23-29), adulthood (age 31-40). Crystallized intelligence revealed a parallel trajectory in the two research groups: A continuous trajectory from older adolescence to adulthood (age 23-40) was found in Vocabulary and Similarities. Semantic Fluency was found to peak at the end of the adolescence period in both groups. Fluid intelligence exhibited a parallel trajectory for both groups in Phonemic Fluency and in the Raven which demonstrated a continuous trajectory: higher scores of adults compared to young adolescents. However, among participants with TD, the Raven test and Phonemic fluency reached their peak at ages 17-18, whereas among participants with ID, the peak was reached at ages 19-21. Block Design revealed a different pattern. The group with TD demonstrated stability from older adolescence to adulthood (age 17-40), whereas the group with ID exhibited a continuous trajectory from older adolescence to adulthood.

Our findings support the Compensation Age Theory (Lifshitz-Vahav, 2015), according to which chronological age plays an important role in determining the cognitive ability among this population beyond their mental age. Our findings refute one of the criteria for intellectual disability, according to the DSM-5: adults with ID can benefit not only from mediated learning experience but also from direct exposure to stimuli. Maturity and life experience help adults with ID to acquire new cognitive skills that were previously absent from their behavioral repertoire (Lifshitz-Vahav, 2015; Luftig, 1987).

LIMITATIONS AND FUTURE RESEARCH

Each of the study populations (with ID and with TD) included 102 participants. Future research, using a broader sample, would help validate the findings for populations with ID. Furthermore, we tested the development of intelligence measures and used the Wechsler test, which is customarily used for measuring intelligence (Canivez & Watkins, 2010). The Wechsler test is used in Israel to determine the intelligence level among both individuals with TD and with ID. However, since these are standard tests that were standardized in a population with TD, they are not sufficiently sensitive for testing differences at a low-performance level. This problem was overcome in some studies (Devenny, Krinsky-McHale, Sersen, & Silverman, 2000; Kittler et al., 2004) by using a version of the children's Wechsler test for adults with ID.

In the present study, the comparison was to a population with TD and the adults with ID could therefore not be tested using the Wechsler for children, and age-adapted tests had to be used. It should be noted that the problem of lack of sensitivity of standard assessment instruments for the low-performance population does not exist solely for the Wechsler test. Most of the assessment instruments for testing cognitive measures among the population with TD are not sufficiently sensitive for testing differences in a low-performance population. In addition, the broad age range (10-40) forced us to use two intelligence tests (WISC and WAIS). This does not enable comparison between the scores of a younger age cohort to the other age cohorts. The comparison between the young adolescents and the other cohorts was based on the effect size, which afforded a general picture regarding each measure.

Future research: Our study is a cross-sectional study in which a comparison of intelligence and memory measures was performed between participants in different age cohorts. A longitudinal study that will follow the cognitive development of the same participants from a young age to adulthood also should be performed, in order to validate the findings. Our study focused on crystallized and fluid intelligence trajectories. It is recommended to examine the trajectory of working and long-term memory. The present study indicates that the population with ID can benefit not only from direct learning but also from direct exposure to stimuli. Other studies using a broad range of crystallized and fluid intelligence tests should be carried in order to validate this finding. The level of the ID of our participants ranges between mild and moderate ID (IQ = 50-70). In future research, it is recommended to examine the cognitive trajectory of individuals with ID with severe and profound ID. The current study focused on participants with non-specific ID. It is recommended to examine the cognitive trajectories among individuals with ID with different etiologies, such as Down syndrome and Williams syndrome.

Educational implications

The Structural Cognitive Modifiability Theory (Tzuriel 2013) postulates that the ability to learn through direct exposure to stimuli depends on a mediated learning experience: "The more the child experiences mediated learning experience interactions, the more he or she is able to learn from direct exposure to formal and informal learning situations, regardless of the richness of stimuli they provide" (Tzuriel, p. 61). It is therefore recommended to expose individuals with ID to mediated learning, especially in younger ages. According to the Compensation Age Theory, the accumulation of exposure to cognitive interventions and mediated learning in younger ages will enable individuals with ID to benefit from direct learning experiences in their adulthood. Action should, therefore be taken to introduce policymakers, administrators and caregiving personnel to the ideas of compensation and growth in adulthood. Staff should be guided to encourage adults with ID to participate in leisure activities more frequently, and to use them as a means for enhancing the cognitive literacy of adults with ID, in addition to the contribution these activities make to their emotional and behavioral functioning. Our research outcomes suggest that leisure activities can serve as a cost-effective and relatively easy tool for use in rehabilitation centers of adults with ID.

Table 1: Background characteristics (CA, General IQ) of participants with ID and TD according to age cohorts (N = 204)

			Chronological age		General IQ			
	Age cohort	*N*	*M*	*SD*	*M*	*SD*	*Min*	*Max*
Participants	10-16	33	13.27	2.03	17.91[1]	3.07	50	70
with ID	17-21	25	18.68	1.28	56.52	5.41	50	70
	23-29	22	26.05	1.94	57.41	4.03	51	68
	31-40	22	35.73	3.34	59.18	5.54	50	68
Participants	10-16	33	13.27	2.03	96.58	6.41	85	108
With TD	17-21	25	18.60	1.19	102.28	4.85	95	109
	23-29	22	25.86	1.83	102.18	5.56	89	109
	31-40	22	35.27	3.03	99.73	5.02	86	106

[1]Raven average raw score

Table 2: Means, SD of the crystallized and fluid tests according to age cohorts and study populations

Tests	Age cohorts	ID			TD			Total		
		N	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*
Vocabulary	17-21	25	9.24	3.26	25	47.84	3.08	50	28.54	19.75
	23-29	22	12.36	6.60	22	50.23	3.35	44	31.30	19.84
	31-40	22	13.82	7.72	22	51.18	3.30	44	32.50	19.79
Similarities	17-21	25	10.12	2.55	25	23.64	1.93	50	16.88	7.19
	23-29	22	10.95	2.77	22	23.77	2.29	44	17.36	6.95
	31-40	22	11.45	2.74	22	25.09	1.85	44	18.27	7.27
Semantic fluency	10-16	33	25.42	6.47	33	53.00	8.44	66	39.21	15.77
	17-21	25	32.32	9.78	25	61.20	6.89	50	46.76	16.82
	23-29	22	32.41	7.72	22	60.86	9.40	44	46.64	16.72
	31-40	22	29.32	9.26	22	64.77	10.16	44	47.05	20.35
Phonemic fluency	10-16	33	11.55	3.35	33	30.76	7.47	66	21.15	11.26
	17-21	25	14.00	5.77	25	44.20	10.70	50	29.10	17.47
	23-29	22	15.32	4.18	22	44.14	11.20	44	29.73	16.80
	31-40	22	15.73	4.44	22	45.00	10.34	44	30.36	16.76
Raven	10-16	33	17.91	3.10	33	56.30	5.80	66	37.11	19.88
	17-21	25	20.56	3.95	25	65.12	2.90	50	42.84	22.76
	23-29	22	21.23	4.29	22	63.91	3.31	44	42.57	21.92
	31-40	22	21.86	4.97	22	63.41	3.77	44	42.64	21.46
Block Design	21-17	25	9.16	5.13	25	46.88	6.04	50	28.02	19.84
	29-23	22	10.05	4.17	22	45.95	7.71	44	28.00	19.17
	40-31	22	13.32	5.47	22	42.41	9.33	44	27.86	16.54

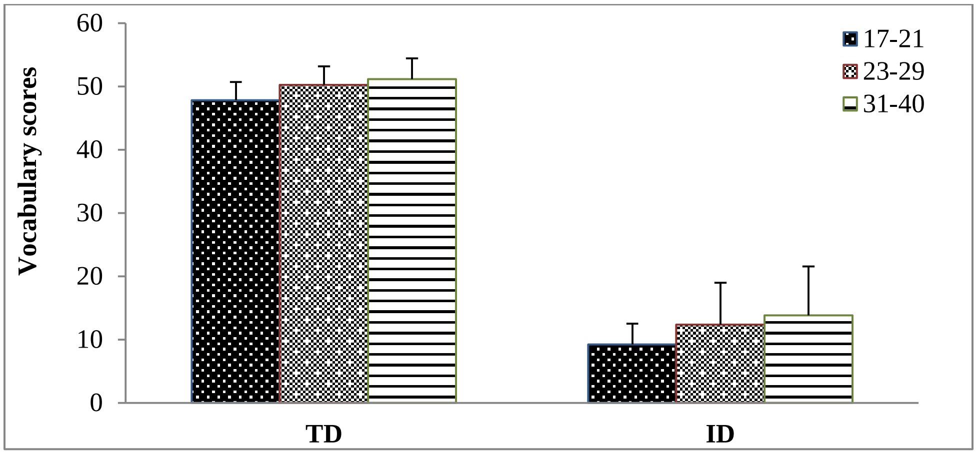

Figure 1: Trajectory of Vocabulary according to age cohorts and study populations

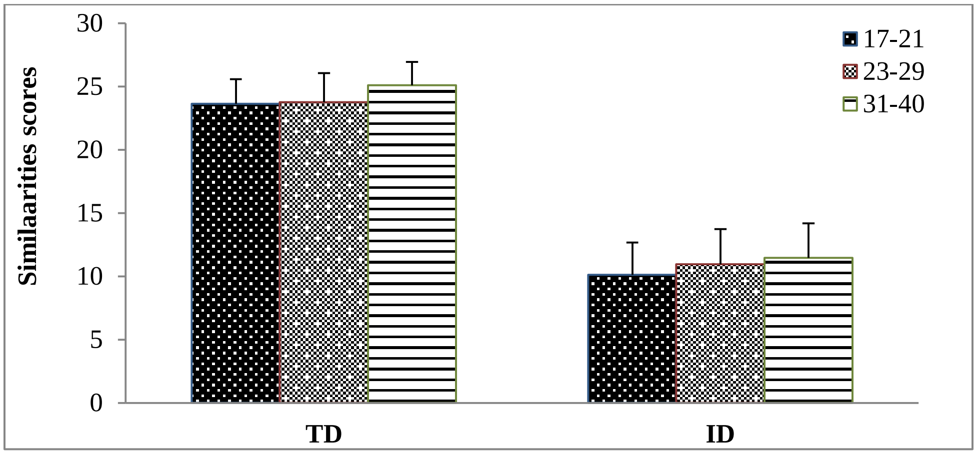

Figure 2: Trajectories of Similarities according to age cohorts and study populations

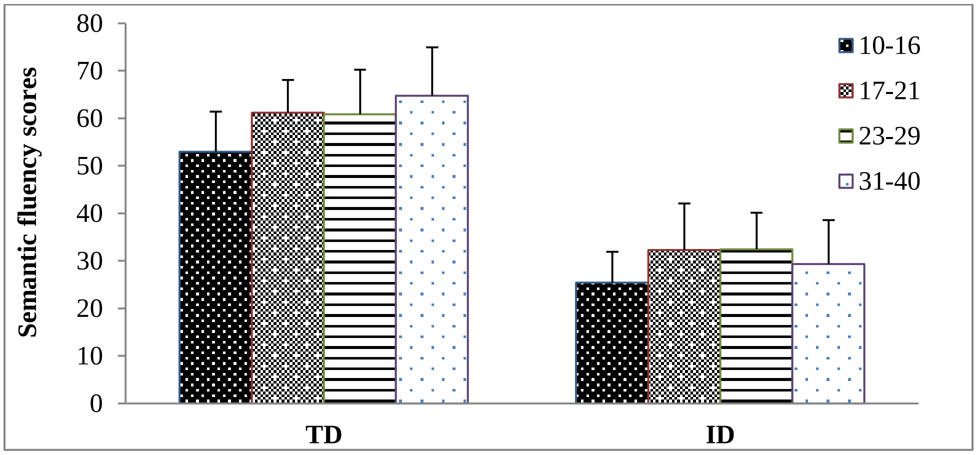

Figure 3: Trajectories of Semantic Fluency according to age cohorts and study populations

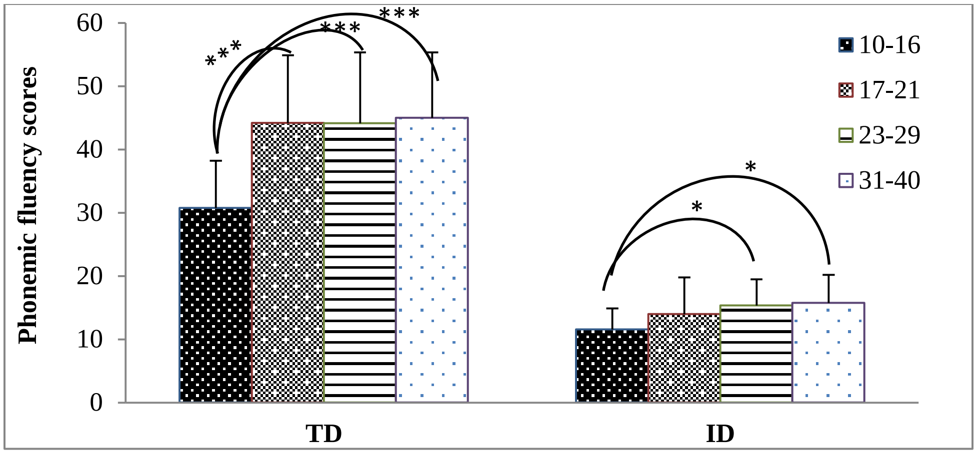

Figure 4: Trajectories of Phonemic Fluency according to age cohorts and study populations

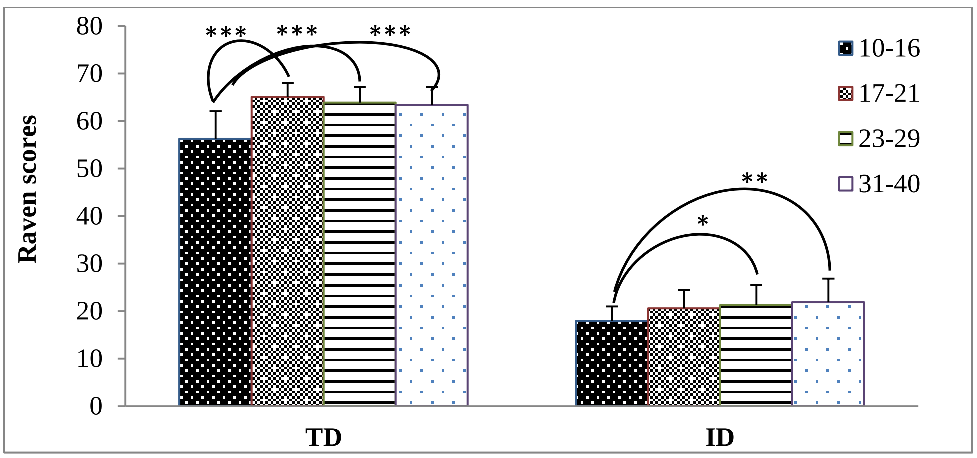

Figure 5: Trajectories of Raven, according to age cohorts and study populations

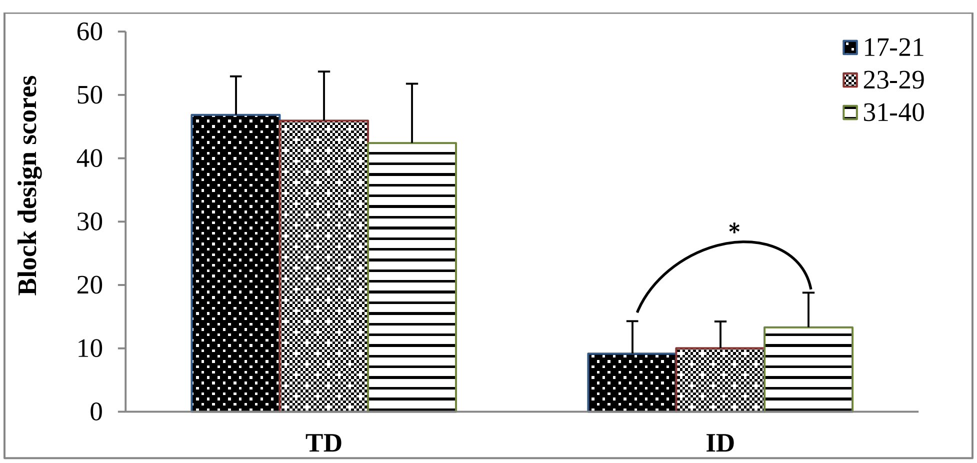

Figure 6: Trajectories of Block design according to age cohorts and study populations

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