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Brain reserve theory: Are adults with intellectual disability more vulnerable to age than peers with typical development?

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Abstract

Background: Life expectancy is on rise and the intriguing question is: When does cognitive decline occur among adults with intellectual disability, compared to adults with typical development? This cross-sectional study examined cognitive performance of crystallised/fluid intelligence, working and long-term memory of adults with intellectual disability of etiologies other than Down syndrome (IQ 50–68) and adults with typical development (IQ 85–114) in four age cohorts (30–39; 40–49; 50–59; 60–69).

Method: The WAIS III^{HEB} and the Rey-AVLT were administered to both groups.

Results: Four patterns of cognitive performance were found: (a) Vocabulary (crystallised intelligence), Spatial Span Forward and Retention yielded similar scores across all four age cohorts in participants with typical development and with intellectual disability. (b) Similarities, Raven and Digit Span Backward exhibit lower scores only in 50–59 or 60–69 compared to the 30–39 age cohort in both groups, (c) Digit Span Forward, Spatial Span Backward and Total Leaning (LTM) yielded lower scores in the 50–59 or 60–69 age cohorts in the typical group, but similar scores in participants with intellectual disability along the age cohorts, (d) Block Design (fluid intelligence) yielded a lower score in the 50–59 cohort versus lower scores only at ages 60–69 in participants with typical development.

Conclusions: Our findings suggest a possible parallel trajectory in age-related cognitive performance for individuals with and without intellectual disability in six measures, and a possible more preserved trajectory in fluid intelligence and some memory measures in adults with intellectual disability compared to their peers. Caution should be exercised regarding Digit and Spatial Span Backwards, which yielded a floor effect in participants with intellectual disability. The Cognitive Reserve Theory, the Safeguard Hypothesis and late maturation might serve as explanations for these findings.

KEYWORDS
adults, cognitive reserve, intellectual disability, intelligence, memory, trajectories, typical development

1 | INTRODUCTION

Today, adults with intellectual disability live to old age, with some reaching ages of 80 and up (Bayen et al., 2018; Heller & van Heumen, 2021). The challenging questions are: When does cognitive decline among adults with intellectual disability occur? Is their pattern of cognitive change similar to that of their peers with typical development in terms of onset and rate of change?

1.1 | Theoretical background

Two possible trajectories of intelligence and cognitive aging have been proposed in individuals with neuro-cognitive disorders, including intellectual disability, compared to the population with typical development (Bathelt et al., 2020; Fisher & Zeaman, 1970; Lifshitz-Vahav, 2015): The *Accelerated aging trajectory* and the *Parallel-stable development trajectory*. These models are based on traditional theories of intelligence (Kaufman, 2001; Wechsler, 1981) in the population with typical development, according to which there is a linear increase in intelligence up to the age of 20, followed by an asymptote, with decline beginning around age 60.

The *Accelerated aging trajectory* could be anchored in the *Cognitive Reserve Theory* (Stern, 2012), which posits that normally occurring differences in how people process tasks might provide differential reserve against age-related changes. Innate characteristics such as level of intelligence determine the cognitive reserve of the individual, as do life events such as educational or occupational experiences and participation in leisure activities (Stern, 2012). Persons with intellectual disability have lower intelligence by definition. In general, most of them study in special education schools (especially in secondary schools) and are excluded from the labour market even in the United States (Rall et al., 2016) and Europe (European Union, 2017). They also have limited access to intellectually stimulating leisure activities (Lancioni et al., 2022). The accelerated trajectory model predicts that individuals with intellectual disability will exhibit restriction in developing intelligence before their twenties (Fisher & Zeaman, 1970), stability thereafter, and accelerated decline in their mid-30s or 40s.

The *parallel-stable development trajectory*: Silverman et al. (2013) and Zigman et al. (2004) compared the rate of Dementia of Alzheimer type among adults with intellectual disability compared to the general population. They found an equal or even lower rate, thus questioning the applicability of the Cognitive Reserve Theory for this population (Wiseman et al., 2015). This trajectory predicts that the intelligence of individuals with intellectual disability reaches its peak in their twenties, after which there is an asymptote and the onset of decline is at age 50–60.

Crystallised and fluid intelligence, working and long-term memory were traced in this study among adults with intellectual disability of etiologies other than Down syndrome from age 30 to 60, compared to age-matched peers with typical development. Our choice in assessing these domains stems from several reasons: (a) Tassé et al. (2016) claimed a correlation between intellectual ability and adaptive behaviour skills: the higher the intellectual functioning, the higher the adaptive behaviour. Murray et al. (2014) found correlation coefficients of 0.51–0.65 between full scale IQ (FSIQ) which represents the *g* (WISC-IV and between crystallised and fluid subscales) and the three components of adaptive behaviour (conceptual, practical and social domains). According to Murray et al. (2014), increments in *g* have important consequences for adaptive behaviour even at low levels of ability. Thus, any change in crystallised and fluid intelligence of adults with intellectual disability might influence their adaptive behaviour functioning. In addition, Feuerstein and Falik (2010) stressed the involvement of cognition in everyday functioning. Inclusion and participation in the community requires manipulation of cognitive skills and strategies, especially in the digital world (Eden, 2020). In light of the above, tracing the changes in intelligence and memory through different stages of adulthood among adults with intellectual disability is of utmost importance.

From a theoretical point of view, and considering the limitation of a cross-sectional study, our findings could indicate whether age-related cognitive performance differs in individuals with and without intellectual disability. From a clinical point of view, it is documented that Dementia of Alzheimer type deterioration begins with cognitive functions (World Alzheimer Report, 2022). Decline in working memory and Block Design visual-motor tests are markers for early signs of Dementia of Alzheimer type in individuals with and without Down syndrome (Krinsky-McHale et al., 2002). Thus, tracing the cognitive performance of the above cognitive domains could help policy makers and services providers to design intervention programmes aimed at delaying the old age and Dementia of Alzheimer type among adults with intellectual disability as much as possible.

The present study focused on adults with intellectual disability of etiologies other than Down syndrome. It is documented that individuals with Down syndrome exhibit triplication of the beta-amyloid precursor protein (β-APP), located on the proximal part of the long arm of chromosome 21. As a consequence, persons with Down syndrome are vulnerable to early decline and Alzheimer disease (Fortea et al., 2021; Startin et al., 2020). However, opposite results have also been reported (Hithersay et al., 2021). This study therefore focused only on adults with intellectual disability of etiologies other than Down syndrome.

1.2 | Crystallised and fluid intelligence abilities

McGrew (2009) redefined the Horn and Cattell (1967) model of crystallised and fluid intelligence. Crystallised intelligence is a person's acquired knowledge of the language, information and concepts of a specific culture. It is considered a 'maintained' ability that increases into the 60s–70s and then declines (Góngora et al., 2020; Rabbitt, 2016). The Vocabulary and Similarities subscales of the Wechsler Intelligence Scale (WAIS) IQ test (Wechsler, 2001) may serve as indices of crystallised intelligence. Fluid intelligence is the use of deliberate and controlled mental operations to solve novel problems that cannot be performed automatically. It is considered a 'vulnerable' ability that peaks in the early twenties and then declines (Kaufman, 2001). It is associated with frontal executive functions (Kaufman, 2001), working memory, and analogy/metaphor understanding. The Block Design subscale of the WAIS IQ test (Wechsler, 2001) may serve as an index of fluid intelligence.

1.3 | Working memory

Working memory refers to a capacity-limited system enabling the simultaneous maintenance and manipulation of information. It is composed of the slave system, which includes the phonological loop, visuospatial sketchpad and episodic buffer, governed by the central executive component. The central executive is responsible for execution of mental processes such as manipulation and integration of information (Baddeley, 2012) and is considered to be age-sensitive, peaking in early adulthood and then declining. There is a lack of consensus regarding the onset age of decline in the population with typical development. Nyberg et al. (2012) found that decline in working memory was dependent on gender, task load and years of education. In the visuospatial domain, decline occurred in women after 31 years of age and in men after age 41. However, the verbal domain decreased significantly among men and women after age 31. The visuospatial domain showed a more pronounced decay with advancing age than the verbal domain. The decline in tasks with a higher level of load is steeper than in tasks with lower load. Kumar et al. (2017) found a steep decline from the 40–50 to the 50–60 age cohort in verbal and visuospatial tasks. The Digit Span Forward and Backward scores were higher than those of Spatial Span Forward and Backward (the scores of Digit and Spatial Span Forward were higher than those of Digit and Spatial Span Backward across all age cohorts). According to Kumar et al., this pattern of decline might classify the adult lifespan into two groups: Before 60 years of age working memory declines steeply, after age 60 there is no change in working memory span.

Age-related changes in working memory among adults with intellectual disability of etiologies other than Down syndrome were studied compared to mental age-matched peers with typical development, but not compared to chronological age-matched peers (Godfrey & Lee, 2018). The scores of adults with intellectual disability in the visuospatial sketchpad were lower than those of mental age-matched children with typical development (Numminen et al., 2002). In our study, age-related changes were examined compared to chronological age-matched peers with typical development using the Digit Span and Spatial Span tests (Wechsler, 2001).

1.4 | Long-term episodic memory

Episodic memory is a component of the declarative long-term memory system (Squire, 2004) and refers to intentional recollection of previously acquired knowledge related to a time or a place (Schacter & Buckner, 1998). A widely-used test for assessing episodic memory is the Rey-Auditory Verbal Learning Test (Rey-AVLT; Vakil & Blachstein, 1997), a word list task assessing learning and recall processes. Episodic memory is thought to remain stable across early to late adulthood, declining from age 60 (Rhodes et al., 2020; Vakil et al., 2010; Vakil & Blachstein, 1997). This study used the Hebrew version of the Rey-AVLT (Vakil et al., 2010; Vakil & Blachstein, 1997) for adults with intellectual disability.

1.5 | Research hypotheses

Aging literature raises two possible trajectories in the population with intellectual disability compared to peers with typical development (Bathelt et al., 2020; Fisher & Zeaman, 1970).

The accelerated trajectory predicts that individuals with intellectual disability will exhibit accelerated decline in their mid-30s or 40s compared to peers with typical development. Our study is cross-sectional. We therefore hypothesized that the participants with typical development will exhibit similar scores across the 30–59 age cohorts, followed by lower scores in the 60–69 cohort, whereas participants with intellectual disability will present highest scores in the 30–39 age cohort, followed by lower scores in each consecutive age cohort.

Contrary to the accelerated trajectory, *the stable-parallel* trajectory predicts that the intelligence of individuals with intellectual disability will peak in their twenties, after which there will be an asymptote and the onset of decline is at age 50–60. We hypothesized that age-related scores among the group with intellectual disability will be similar to those of the group with typical development, except for a difference in the baseline IQ. Each group will exhibit similar scores across age cohorts followed by lower scores in the 60–69 compared to the 50–59 age cohort. We further hypothesized that fluid intelligence ability and the central executive component of the working memory will exhibit relatively lower scores with the consecutive age cohorts than crystallised intelligence (Rabbitt, 2016).

2 | METHOD

2.1 | Participants

The sample included 83 Hebrew speakers with typical development (46%; $N = 38$ men) and 100 participants with intellectual disability of etiologies other than Down syndrome (54%; $N = 56$ men), with no significant difference in gender distribution between the groups, $\chi^2(1) = 1.89$, $p > .05$. An independent samples t-test indicated no significant differences in chronological age, $t(181) = .04$, $p > .05$, between the group with typical development ($M = 49.50$, $SD = 11.98$) and the group with intellectual disability ($M = 49.49$, $SD = 11.17$). Both groups were divided into four age cohorts (30–39, 40–49, 50–59, 60–69).

2.1.1 | Participants with typical development

Adults with typical development were recruited from municipal or government offices, teachers and kindergarten teachers who had a mean of 15 years of schooling (BA degree), with no significant differences between the various age cohorts. The call for participants was by advertising the study on the university bulletin boards, in local community learning centres, in municipal authority organisations, in the government workers' organisation, in the teachers and kindergarten teachers' organisation as well as by a general email distribution. The participants were recruited using a convenience sample.

These participants have an average income, according to the Israel Central Bureau of Statistics (2021). Senior participants over the age of 60 were recruited from enrichment academic programmes for senior citizens at the university and at local community centres (these participants were also in the group that earned an average income in their past). Inclusion criteria were: (a) A minimum score of 8 in the Vocabulary subtest (Wechsler, 2001) as an indicator of fluent Hebrew (all participants were native Hebrew speakers). One-way ANOVA indicated no significant differences in the Vocabulary scale score between age cohorts, $F(3, 79) = 1.03$, $p > .05$, $\eta_p^2 = .03$ (see Table 1). No additional information on linguistic background was collected. (b) An education level of at least 12 years. One-way ANOVA indicated no significant differences in education level between age cohorts, $F(3, 79) = .63$, $p > .05$, $\eta_p^2 = .02$ (see Table 1). (c) Verbal IQ and performance IQ scores within one standard deviation from the mean normal IQ score (85–115 IQ points; Wechsler, 2001). This criterion allowed proper discrimination, since 68% of the normative range is distributed between one standard deviation above/below the normative mean. One hundred and twenty-nine participants with typical development across age cohorts 30–69 were recruited. Of these, 46 were excluded since their IQ levels were lower or higher than one standard deviation from the norm ($M = 100$, $SD = 15$). One-way ANOVAs indicated no significant differences in verbal IQ level, $F(3, 79) = .74$, $p > .05$, $\eta_p^2 = .02$, or performance IQ, $F(3, 79) = .84$, $p > .05$, $\eta_p^2 = .03$, between age cohorts (see Table 1). Participants with typical development received a monetary reward for participation in the study.

2.1.2 | Participants with intellectual disability of etiologies other than Down syndrome

All participants with intellectual disability live in residential settings under the supervision of the Disability Division, the Israel Ministry of Welfare and Social Affairs. In the mornings they work in a vocational centre and in the afternoons they participate in leisure activities. After receiving all the authorizations (the University Ethics Committee, the Bar-Ilan University Faculty of Education and the Division of Disability in the Ministry of Welfare), we turned to the services providers of the community residence and vocational workshops. They prepared a list of adults with *intellectual disability of etiologies other than Down syndrome* in their residential or vocational facilities according to the following inclusion criteria: (a) A valid diagnosis of mild/moderate intellectual disability (American Psychiatric Association, 2013), residence and occupation in the community or in supervised workshops; (b) healthy according to their personal files, (c) without signs of deterioration or dementia of any type, (d) without serious sensory impairments (blindness/deafness), uncontrolled seizures or maladaptive behaviours. Information on the intellectual disability level was taken from personal files. The directors asked participants with intellectual disability their permission to participate in a esearch, and if the answer was positive they referred them to our principal investigator (see Procedure section). Ten adults refused to participate in the study. Additional assessments of verbal and performance IQ levels were conducted (see below). One-way ANOVAs indicated no significant differences in verbal IQ level, $F(3, 96) = 2.38$, $p > .05$, $\eta_p^2 = .06$, or performance IQ, $F(3, 96) = 1.70$, $p > .05$, $\eta_p^2 = .05$, between age cohorts. All participants with intellectual disability studied in special education schools for students with intellectual disability from age 6 to age 21. They entered the community residence in their twenties. There is no information regarding their family's socioeconomic status. Table 1 presents the distribution of the groups with typical development and intellectual disability according to age cohorts and IQ scores.

2.2 | Assessment tools

2.2.1 | Intelligence

IQ was calculated according to three subscales of the WAIS III[HEB] (Wechsler, 2001): Vocabulary, Similarities, Matrix and Block Design, which are indicators of general intelligence according to the WASI™ (Wechsler Abbreviated Scale of Intelligence, Wechsler, 1999). This procedure was used in a population with typical development (Canivez et al., 2009) and in a population with intellectual disability (Gawrylowicz et al., 2012; Lifshitz et al., 2021). We used the raw scores in all tests, since the process of converting them to scaled scores conceals a hidden assumption that age-related differences across the lifespan in the research group is similar to that of the control group.

2.2.2 | Crystallised intelligence battery

Raw scores from two Wechsler subtests (WAIS-III[HEB], Wechsler, 2001) measuring crystallised intelligence were used, since standard scores account for chronological age and we wanted to examine possible changes in abilities in four age cohorts. *Vocabulary* assessed expressive word knowledge, verbal concept formation, and fund of knowledge (33 items; scores: 0–66). *Similarities* assessed conceptualization of dissimilar objects (19 items; scores: 0–33).

2.2.3 | Fluid intelligence battery (raw scores)

Block Design (WAIS-III[HEB], Wechsler, 2001) assessed analysis and synthesis of abstract visual stimuli, visual perception and organisation, simultaneous processing, and visual-motor coordination (14 items; scores: 0–33). *Matrix* (WAIS-III[HEB]) included four types of problems:

TABLE 1 Means of chorological age, education level, vocabulary scale score, verbal IQ level, performance IQ level for TD group by age-cohort

		Typical development				Intellectual disability of etiologies other than down syndrome			
		30–39 ($n = 21$)	40–49 ($n = 20$)	50–59 ($n = 20$)	60–69 ($n = 22$)	30–40 ($n = 25$)	40–49 ($n = 24$)	50–59 ($n = 28$)	60–69 ($n = 23$)
Chronological age	*M*	33.87	43.85	55.80	63.82	34.53	44.53	55.04	63.47
	SD	(3.40)	(2.91)	(2.78)	(2.75)	(3.09)	(2.69)	(2.54)	(2.10)
	Range	30.00–39.10	40.02–49.04	51.05–59.08	60.01–68.07	30.00–39.09	40.00–49.00	51.00–59.04	60.08–67.08
Education level[a]	*M*	15.23	15.15	14.80	14.63				
	SD	(1.48)	(1.75)	(1.64)	(1.73)				
	Range	12.00–17.00	12.00–17.00	12.00–17.00	12.00–17.00				
Vocabulary Scale Score	*M*	11.19	10.55	11.10	10.86				
	SD	(1.24)	(1.27)	(1.37)	(1.16)				
	Range	9.00–13.00	9.00–14.00	8.00–13.00	9.00–13.00				
Verbal IQ level	*M*	93.61	91.65	93.30	92.67	59.04	58.37	60.39	61.21
	SD	(5.85)	(2.85)	(4.84)	(5.44)	(3.06)	(4.49)	(4.61)	(3.87)
	Range	45.00	35.50	25.50	32.50	52.00–66.00	52.00–70.00	50.00–68.00	54.00–68.00
Performance IQ level	*M*	105.66	104.00	102.75	102.54	57.84	56.96	58.71	59.08
	SD	(5.54)	(7.39)	(7.97)	(7.51)	(4.48)	(2.29)	(3.52)	(3.64)
	Range	45.00	35.50	25.50	32.50	50.00–37.00	54.00–63.00	54.00–69.00	52.00–67.00

[a]All participants with intellectual disability studied in special education schools from age 6 to 21.

pattern completion, classification, analogies and serial inference (26 items; scores 0–26).

Working memory included the Digit Span test (WAIS-III, Wechsler, 1997a, 2001) and the Spatial Span test of WMS-III (Wechsler, 1997b). Digit Span measures verbal short-term and working memory. The Forward Span task requires verbal working memory and attention (8 items; scores 0–16). The Backward Span task includes cognitive control and executive function (7 items; scores 0–14). The Spatial Span subtest (WMS-III, Wechsler, 1997b) is composed of 10 blocks affixed on a board which are numbered randomly only on the examiner's side. The examiner creates eight sequences at an ascending level of difficulty. In the Spatial Span Forward, the task is to touch the blocks in the same order as the examiner, whereas in the Spatial Span Backward it is to touch on the blocks in the reverse order. Scores: 0–2 for each item (16 items; scores 0–32).

2.2.4 | Long-term episodic memory

The Rey-AVLT (Vakil et al., 2010; Vakil & Blachstein, 1997) includes 15 common nouns (word list A) in five consecutive reading trials, by a free recall test, then a free recall of word list B (Trial 6), a free recall of word list A again (Trial 7) and after a 20 min delay (Trial 8). The sum of words recalled across trials 1–5 produced a Total Learning score. The last learning (Trial 5) minus delayed recall (Trial 8) produced a Retention score which reflects the number of words forgotten between the two trials (Vakil & Blachstein, 1997).

2.3 | Procedure

Authorizations were obtained from the University Ethics Committee, the Bar-Ilan University Faculty of Education and the Division of Disability in the Ministry of Welfare. Adults with typical development signed an informed consent form. Adults with intellectual disability provided an informed consent signed by their legal guardians. The study aim and procedure were explained to them by the principal investigator (a PhD student who worked with adults with intellectual disability) and they signed an adapted informed consent form for participation of individuals with intellectual disability in scientific research. Participants were able to leave the study at any time, without losing their reward. According to the normalisation principle (Wolfensberger, 2002) and like participants with typical development, participants with intellectual disability received monetary reward for participation in the study.

Our experience in assessing cognitive tests among individuals with intellectual disability (Lifshitz et al., 2021; Shnitzer-Meirovich et al., 2018) indicates that adults with intellectual disability can concentrate between 1 and 1.5 h with a break in the middle. Based on this, and to prevent mental fatigue, the tests battery was divided into two sessions. In the first session, the four WAIS-III^{HEB} subtests were administered (approx. 1 h, after which there was a 15 min break during which refreshments were served). One day later, we first administered the mMatrix (lasting approx. 45 min) and then, after a 15 min break, we administered the memory tests. To avoid cognitive load, auditory-verbal memory tests were administered before or after one of the nonverbal tests (Matrix and Block design). These two tests were administered randomly, to avoid the order effect.

The tests were administered by the first author, under the supervision of a psychologist in the field of intellectual disability who also calculated the IQ scores. The tests were administered in the employment settings (in the morning) or in residential places (after the lunch break) according to the participants' request. Some of the participants preferred to be assessed in the employment settings during work and some preferred to be assessed after working hours and lunch break.

2.4 | Statistical analysis

Age-related differences in study measures were analysed using IBM SPSS software version 19. Before examining the study questions and hypotheses, we conducted Shapiro–Wilk tests in order to examine whether the dependent variables had a normal distribution in each group (typical development, non-specific intellectual disability), and for each age cohort (30–39; 40–49; 50–59; 60–69). The distribution of nearly all dependent variables deviated significantly from a normal distribution. We therefore examined the study questions and hypotheses using non-parametric tests. Non-parametric Kruskal–Wallis tests were conducted in order to examine age-related differences in the dependent variables among each group. Bonferroni correction was applied to reduce the probability of a type I error. A one-sided $p < .01$ value was applied as a criterion for significance.

Although research questions and hypotheses were not specified for age-related differences a priori for both groups, the theoretical background supported hypotheses regarding age-related trends (sensitive/not sensitive to age; Craik & Bialystok, 2006; Horn & Cattell, 1966; Spreng & Turner, 2019; Wechsler, 2001).

The results among the group with typical development in the Raven Matrix, Block Design, Digit Span Forward and Backward, Spatial Span Forward and Backward (Wechsler, 1997b, 2001) obtained by the non-parametric statistical methodology were not coherent with the robust theoretical knowledge on age-related trends (Craik & Bialystok, 2006; Horn & Cattell, 1967; Spreng & Turner, 2019; Wechsler, 1997b, 2001). In addition, each age cohort in our study contained more than 20 participants, which is sufficient for parametric statistical analysis (Grech & Calleja, 2018). We therefore used the parametric statistical analysis.

Two-way ANOVAs (2 x 4) with Bonferroni correction were conducted with group and age cohort as independent variables and the cognitive tests battery (Vakil et al., 2010; Vakil & Blachstein, 1997; Wechsler, 1997b, 2001) as dependent variables, producing information about main effects for group and for age cohort and information about group × age cohort interactions. Main effects for group were inherent to the research group compared to the control group. Least Significant Difference (LSD) post hoc tests of ANOVA (Fisher, 1935) were used to reveal the source

TABLE 2 Mean, *SD*, Median scores in the study measures according to group and age cohort (30–39; 40–49; 50–59; 60–69)

		Typical development				Intellectual disability of etiologies other than down syndrome			
		30–39 (*n* = 21)	40–49 (*n* = 20)	50–59 (*n* = 20)	60–69 (*n* = 22)	30–40 (*n* = 25)	40–49 (*n* = 24)	50–59 (*n* = 28)	60–69 (*n* = 23)
Vocabulary	*M*	47.81	47.20	46.75	45.18	10.52	10.08	10.11	9.30
	SD	(3.40)	(2.91)	(5.73)	(5.04)	(3.21)	(3.25)	(4.40)	(2.10)
	Mdn	49.00	47.50	45.00	44.00	11.00	10.00	10.00	9.00
Similarities	*M*	24.28	23.10	23.10	22.22	10.16	8.50	8.17	6.95
	SD	(2.36)	(2.78)	(3.72)	(3.47)	(2.48)	(3.00)	(2.40)	(2.49)
	Mdn	24.00	24.00	24.00	22.00	11.00	7.50	8.50	7.00
Matrix	*M*	18.95	18.70	16.55	16.22	4.76	4.33	4.10	3.73
	SD	(1.96)	(3.18)	(2.78)	(3.59)	(2.48)	(1.23)	(.83)	(1.05)
	Mdn	18.00	18.50	17.00	17.00	4.00	4.00	4.00	4.00
Block design	*M*	42.52	37.50	35.40	31.13	9.72	7.91	7.32	6.26
	SD	(6.03)	(6.71)	(8.84)	(5.72)	(4.28)	(3.74)	(3.51)	(3.03)
	Mdn	45.00	35.50	25.50	32.50	9.00	7.50	6.50	6.00
Digit Span Forward	*M*	10.52	10.85	10.10	9.36	4.60	5.70	4.71	5.69
	SD	(1.96)	(1.30)	(1.58)	(1.39)	(1.82)	(2.54)	(1.94)	(1.96)
	Mdn	11.00	11.00	10.00	9.00	5.00	6.00	5.00	5.00
Digit Span Backward	*M*	7.66	7.50	6.65	6.36	2.28	1.95	1.92	1.73
	SD	(2.10)	(1.79)	(1.53)	(2.30)	(1.69)	(1.36)	(1.21)	(1.28)
	Mdn	8.00	8.00	7.00	7.00	2.00	2.00	2.00	2.00
Spatial Span Forward	*M*	8.09	7.95	7.30	7.22	2.84	2.83	2.71	2.65
	SD	(1.60)	(1.66)	(1.54)	(1.37)	(1.51)	(1.65)	(1.53)	(1.15)
	Mdn	8.00	8.00	7.50	7.00	2.00	3.00	2.00	2.00
Spatial Span Backward	*M*	7.19	6.55	6.15	5.54	1.48	1.83	1.67	1.82
	SD	(1.28)	(1.09)	(1.30)	(1.33)	(.65)	(1.30)	(.66)	(.65)
	Mdn	7.00	6.00	6.00	6.00	2.00	2.00	2.00	2.00
Total learning	*M*	42.04	37.50	35.10	30.68	18.00	17.45	17.10	17.78
	SD	(4.91)	(6.90)	(6.00)	(5.85)	(6.70)	(6.76)	(4.39)	(5.54)
	Mdn	41.00	39.00	34.50	29.50	15.00	17.00	16.00	16.00
Retention	*M*	1.80	1.90	2.05	2.77	1.40	1.50	1.60	1.56
	SD	(2.13)	(2.38)	(1.93)	(1.99)	(2.32)	(2.24)	(2.09)	(1.67)
	Mdn	2.00	1.00	1.50	3.00	1.00	1.00	1.50	2.00

of the differences for age cohorts and group × age cohort interactions. This parametric statistical design produced a holistic inquiry of the research questions and hypotheses. The results of this inquiry are reported below, followed by the non-parametric Kruskal–Wallis tests as a comparison.

2.5 | Findings

Descriptive statistics in study measures for group (typical development/non-specific intellectual disability) and age cohort (30–39; 40–49; 50–59; 60–69) are presented in Table 2.

2.5.1 | Crystallised intelligence

Age-related differences in crystallised intelligence (Horn & Cattell, 1967) were assessed by two measures, Vocabulary and Similarities WAIS-III tests (Wechsler, 2001).

2.5.2 | Vocabulary

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 3210.07$, $p < .05$, $\eta_p^2 = .95$, with a higher score for the group with typical development ($M = 47.61$, $SD = 4.95$) compared to the group with intellectual disability ($M = 10.02$, $SD = 3.78$). The main effect of age cohort was non-significant, $F(3, 175) = 1.57$, $p > .05$, $\eta_p^2 = .02$, as was the group × age cohort interaction, $F(3, 175) = .24$, $p > .05$, $\eta_p^2 = .00$. Thus, the Vocabulary test was not sensitive to age for both groups, indicating a similar cognitive performance among adults with typical development and with non-specific intellectual disability. Kruskal–Wallis non-parametric tests yielded similar results for the group with typical development ($\chi^2(3) = 3.37$, $p > .05$) and the group with intellectual disability ($\chi^2(3) = 2.45$, $p > .05$).

2.5.3 | Similarities

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 1191.78$, $p < .05$, $\eta_p^2 = .87$, with a higher score for the group with typical development ($M = 23.16$, $SD = 3.16$) compared to the group with intellectual disability ($M = 8.47$, $SD = 2.82$). A significant main effect was also found for age cohort, $F(3, 175) = 6.44$, $p < .05$, $\eta_p^2 = .10$. LSD post-hoc analysis showed significant a lower score in the 60–69 compared to the 30–39 age cohort in both groups. No other significant differences were found between the age cohorts. The group × age cohort interaction was non-significant, $F(3, 175) = .33$, $p > .05$, $\eta_p^2 = .00$. Thus, the Similarities test was sensitive to age for both groups, indicating a parallel cognitive performance along the age cohorts among both groups of adults. The non-parametric methodology did not reach significance for the group with typical development ($\chi^2(3) = 4.03$, $p > .05$), but did reach significance in mean ranks for age cohort in the group with intellectual disability ($\chi^2(3) = 17.90$, $p < .05$).

2.5.4 | Fluid intelligence

Age-related differences in fluid intelligence (Horn & Cattell, 1967) were assessed by two measures, Matrix WAIS-III test and Block Design WAIS-III test (Wechsler, 2001), as described below.

2.5.5 | Matrix

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 1546.16$, $p < .05$, $\eta_p^2 = .89$, with a higher score for the group with typical development ($M = 17.59$, $SD = 3.15$) compared to the group with intellectual disability ($M = 10.29$, $SD = 7.08$). The main effect of age cohort was also significant, $F(3, 175) = 7.09$, $p < .05$, $\eta_p^2 = .10$. LSD post hoc analyses showed lower scores in the 50–59 and 60–69 compared to the 30–39 and 40–49 age cohorts. No other significant differences were found between the age cohorts. The group × age cohort interaction was non-significant, $F(3, 175) = 2.38$, $p > .05$, $\eta_p^2 = .03$. The Matrix test was sensitive to age in a parallel trajectory of decline among the adults of both groups. The Kruskal–Wallis non-parametric test reached significance for the group with typical development ($\chi^2(3) = 10.65$, $p < .05$), but not for the group with intellectual disability ($\chi^2(3) = 2.43$, $p > .05$).

2.5.6 | Block design

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 1300.22$, $p < .05$, $\eta_p^2 = .88$, with a higher score for the group with typical development ($M = 36.57$, $SD = 7.96$) compared to the group with intellectual disability ($M = 7.82$, $SD = 3.83$). The main effect of age cohort was also significant, $F(3, 175) = 14.96$, $p < .05$, $\eta_p^2 = .20$, as was the group × age cohort interaction, $F(3, 175) = 4.25$, $p < .05$, $\eta_p^2 = .06$.

A one-way ANOVA for each group indicated significant differences between age cohorts for the group with typical development, $F(3, 79) = 10.07$, $p < .05$, $\eta_p^2 = .27$ and for the group with intellectual disability, $F(3, 96) = 3.77$, $p < .05$, $\eta_p^2 = .10$. LSD post hoc analyses for the group with typical development yielded a lower score in the 60–69 compared to the 30–39 and 40–49 age cohorts. The score in the 50–59 age cohort was lower than in the 30–39 age-cohort. For the group with intellectual disability, the score in the 60–69 age cohort was lower than in the 30–39 age cohort. Thus, the age-related performance in the Block Design test was sensitive to age in both groups, but the lower scores with higher age cohort among the group with intellectual disability was moderate compared to the group with typical development. The non-parametric methodology showed an uneven picture, as Kruskal–Wallis tests reached significance for the group with typical development ($\chi^2(3) = 22.08$, $p < .05$), but not for the group with intellectual disability ($\chi^2(3) = 9.10$, $p > .05$).

2.5.7 | Working memory

Age-related differences in working memory (Baddeley, 2012) were assessed by four measures, Digit-Span Forward and Backward WAIS-III tests (Wechsler, 2001), Spatial Span Forward and Backward WMS-III tests (Wechsler, 1997b), as detailed below.

2.5.8 | Digit span forward

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 325.84$, $p < .05$, $\eta_p^2 = .65$, with a higher score for the group with typical development ($M = 10.19$, $SD = 1.65$) compared to the group with intellectual disability ($M = 5.15$, $SD = 2.11$). The main effect of age cohort was non-significant, $F(3, 175) = 1.97$, $p > .05$, $\eta_p^2 = .03$, but the group × age cohort interaction was significant, $F(3, 175) = 3.00$, $p < .05$, $\eta_p^2 = .04$. One-way ANOVAs for each group indicated significant differences between age cohorts for the group with typical development, $F(3, 79) = 3.47$, $p < .05$, $\eta_p^2 = .11$, but not for the group with intellectual disability, $F(3, 96) = 2.09$, $p > .05$, $\eta_p^2 = .06$. LSD post hoc analysis for the group with typical development indicated a lower score in the 60–69 compared to the 30–39 and 40–49 age cohorts. No other differences were found. The Digit-Span Forward test was sensitive to age for the group with typical development, but not for the group with intellectual disability, with a declining trajectory among adults with typical development and a stable trajectory among adults with intellectual disability. Kruskal–Wallis tests did not reach significance for the group with typical development ($\chi^2(3) = 9.93$, $p > .05$) or the group with intellectual disability ($\chi^2(3) = 4.59$, $p > .05$).

2.5.9 | Digit span backward

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 411.75$, $p < .05$, $\eta_p^2 = .70$, with a higher score among the group with typical development ($M = 7.03$, $SD = 2.00$) compared to the group with intellectual disability ($M = 1.98$, $SD = 1.39$). The main effect of age cohort was significant, $F(3, 175) = 2.79$, $p < .05$, $\eta_p^2 = .04$. LSD post hoc analysis indicated lower scores in the 50–59 and 60–69 compared to the 30–39 age cohort. No other significant differences were found between the age cohorts. The group × age cohort interaction was non-significant, $F(3, 175) = .85$, $p > .05$, $\eta_p^2 = .01$. To summarise, the Digit Span Backward test was sensitive to age for both groups, indicating a parallel trajectory of decline among both groups of adults. The results for the group with intellectual disability should be interpreted with caution, because of a concern for a floor effect, since 13% of these participants received a raw score of zero. Kruskal–Wallis tests did not reach significance for the group with typical development ($\chi^2(3) = 6.79$, $p > .05$) or for the group with intellectual disability ($\chi^2(3) = 1.01$, $p > .05$).

2.5.10 | Spatial span forward

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 475.85$, $p < .05$, $\eta_p^2 = .73$, with a higher score for the group with typical development ($M = 7.63$, $SD = 1.55$) compared to the group with intellectual disability ($M = 2.76$, $SD = 1.46$). The main effect of age cohort was non-significant, $F(3, 175) = 1.42$, $p > .05$, $\eta_p^2 = .02$, as was the group × age cohort interaction, $F(3, 175) = .63$, $p > .05$, $\eta_p^2 = .01$. The Spatial Span Forward test was not sensitive to age for both groups, which might indicate similar stable trajectories in both groups of adults. The non-parametric method yielded similar results, as Kruskal–Wallis tests did not reach significance for the group with typical development ($\chi^2(3) = 4.72$, $p > .05$) or for the group with intellectual disability ($\chi^2(3) = .25$, $p > .05$).

2.5.11 | Spatial span backward

A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 869.20$, $p < .05$, $\eta_p^2 = .83$, with a higher score for the group with typical development ($M = 6.34$, $SD = 1.83$) compared to the group with intellectual disability ($M = 1.70$, $SD = .85$). The main effect of age cohort was significant, $F(3, 175) = 3.35$, $p < .05$, $\eta_p^2 = .05$, as was the group × age cohort interaction, $F(3, 175) = 6.80$, $p < .05$, $\eta_p^2 = .10$. One-way ANOVAs for each group showed significant differences between age cohorts for the group with typical development, $F(3, 79) = 6.40$, $p < .05$, $\eta_p^2 = .19$, but not for the group with intellectual disability, $F(3, 96) = .91$, $p > .05$, $\eta_p^2 = .02$. LSD post hoc analysis for the group with typical development yielded a lower score in the 60–69 compared to the 30–39 and 40–49 age cohorts. The score in the 50–59 age cohort was lower than in the 30–39 age cohort. It seemed that the Spatial Span Backward measure was sensitive to age for the group with typical development, which might indicate an age trajectory of decline among adults with typical development. The results for the group with intellectual disability should be interpreted with caution, because of a concern for a floor effect, since 9% of these participants received a raw score of zero. The non-parametric methodology mirrored a similar picture, as Kruskal–Wallis tests reached significance for the group with typical development ($\chi^2(3) = 16.03$, $p < .05$), but not for the group with intellectual disability ($\chi^2(3) = .3.50$, $p > .05$).

2.5.12 | Episodic long-term memory

Age-related differences in episodic long-term memory (Squire, 1992, 2004) were assessed by two measures extracted from Rey's AVLT (Vakil et al., 2010; Vakil & Blachstein, 1997).

2.5.13 | Total learning

Total learning is a composite score reflecting the number of words acquired across the first five trials of the Rey-AVLT. A two-way ANOVA (2 x 4) indicated a significant main effect for group, $F(1, 175) = 454.14$, $p < .05$, $\eta_p^2 = .72$, with a higher score for the group with typical development ($M = 36.26$, $SD = 7.18$) compared to the group with intellectual disability ($M = 17.57$, $SD = 5.80$). The main effect of age cohort was significant, $F(3, 175) = 7.71$, $p < .05$, $\eta_p^2 = .11$, as was the group × age cohort interaction, $F(3, 175) = 6.96$, $p < .05$, $\eta_p^2 = .10$. One-way ANOVAs for each group yielded significant differences between age cohorts for the group with typical development, $F(3, 79) = 13.63$, $p < .05$, $\eta_p^2 = .34$, but not for the group with intellectual disability, $F(3, 96) = .11$, $p > .05$, $\eta_p^2 = .00$. LSD post hoc analysis for the group with typical development indicated the highest score in the 30–39 age cohort compared to all other age cohorts. The score in the 40–49 age cohort did not differ from the 50–59 age-cohort, but was higher than the score of the 60–69 age cohort. Thus, the age-related performance in the Total Learning Rey-AVLT measure differed by group. The age trajectory for the group with typical development was sensitive to age, while for the group with intellectual disability it was stable. The non-parametric methodology yielded a similar picture, as Kruskal–Wallis tests reached significance for the group with typical development ($\chi^2(3) = 27.02$, $p < .05$), but not for the group with intellectual disability ($\chi^2(3) = .20$, $p > .05$).

2.5.14 | Retention

Retention indicates retrieval efficiency or forgetting rate. It is obtained by subtracting the score of a 20 min delayed recall (Trial 8) of the final learning of word list A (Trial 5). A two-way ANOVA (2 x 4)

TABLE 3 Age-related sensitivity in intelligence and memory by group

Measure	Test	Age-related performance by group		Conclusion
		TD	ID	
Crystallised Intelligence	Vocabulary	NS	NS	Parallel-similar cognitive performance along the age cohorts.
	Similarities	60–69	60–69	Parallel lower scores in these age cohorts.
Fluid Intelligence	Matrix	50–59	50–59	Parallel lower scores in these age cohorts.
	Block Design	50–59	60–69	Lower scores at older age cohorts in participants with ID compared to TD
Working memory	Digit Span Forward	60–69	NS	Lower scores in participants with TD. Similar scores participants with ID
	Digit Span Backward	50–59	50–59	Lower scores in participants with TD and ID (floor effect in 13% of the participants with ID).
	Spatial Span Forward	NS	NS	Parallel-similar cognitive performance along the age cohorts.
	Spatial Span Backward	50–59	NS	Lower scores in participants with TD. Similar scores in participants with ID (floor effect in 9% of the participants with ID)
Episodic Long-Term Memory	Total Learning	40–49	NS	Lower scores in participants with TD. Similar scores in participants with ID.
	Retention	NS	NS	Parallel-similar cognitive performance along the age cohorts.

Abbreviations: ID, intellectual disability of etiologies other than Down syndrome; NS, non-significant differences in scores along the four age cohorts; TD, typical development.

indicated a significant main effect for group, $F(1, 175) = 7.58$, $p < .05$, $\eta_p^2 = .04$, with a higher score for the group with intellectual disability ($M = 1.28$, $SD = 2.12$) compared to the group with typical development ($M = 2.14$, $SD = 2.11$) (a lower score indicates less forgetting). The main effect of age cohort was non-significant, $F(3, 175) = 1.64$, $p > .05$, $\eta_p^2 = .03$, as was the group × age cohort interaction, $F(3, 175) = .66$, $p > .05$, $\eta_p^2 = .01$. The Retention measure was not sensitive to age for both groups, which might indicate similar stable trajectories between both groups of adults. The non-parametric methodology mirrored a similar picture, as Kruskal–Wallis tests did not reach significance for the group with typical development ($\chi^2(3) = 3.92$, $p > .05$) or for the group with intellectual disability ($\chi^2(3) = 3.43$, $p > .05$).

A summary of the results is presented in Table 3.

3 | DISCUSSION

This cross-sectional study examined the age-related cognitive performance changes in adults with intellectual disability of etiologies other than Down syndrome in crystallised and fluid intelligence, working and long-term memory in four age cohorts, compared to age-matched peers with typical development.

Our findings refute the first hypothesis of an accelerated trajectory in the population with intellectual disability. The participants with intellectual disability did not demonstrate lower scores in younger age cohorts in any of the measures compared to their peers with typical development. The second hypothesis of a parallel stable trajectory between the groups with typical development and with intellectual disability was partially supported. Four patterns of cognitive performance were found: (a) Vocabulary (crystallised intelligence), Spatial Span Forward and Retention yielded similar scores across all four age cohorts in participants with typical development and with intellectual disability. (b) Similarities, Raven and Digit Span Backward exhibited lower scores only in 50–59 or 60–69 compared to the 30–39 age cohort in both groups, (c) Digit Span Forward, Spatial Span Backward and Total Leaning (LTM) yielded lower scores in the 50–59 or 60–69 age cohorts in the typical group, but similar scores in participants with intellectual disability along the age cohorts, (d) Block Design (fluid intelligence) yielded a lower score in the 50–59 cohort versus lower scores only at ages 60–69 in participants with intellectual disability. Digit and Spatial Span Backward yielded floor effect in participants with intellectual disability. The pattern of the cognitive performance between the two groups will be at the core of the discussion.

3.1 | Crystallised intelligence

The adults with intellectual disability exhibited similar scores in Vocabulary across the age cohorts from their 30s until after age 60, similarly to the population with typical development, indicating a parallel trajectory. Our findings are in line with results for the population with typical development that may continue to develop crystallised intelligence into their 60s or 70s (Kaufman, 2001; Salthouse, 2019; Schaie, 2013; and see Chen et al., 2017 for a typical Israeli sample). Our findings are also in agreement with those of Carr and Collins (2018), who reported stability from ages 30 to 50 on the British Picture Vocabulary Scale (Dunn et al., 1982) and only a small but non-significant drop (0.99) from ages 21 to 50 on the preschool version of the Wechsler (1967) in individuals with Down syndrome. The authors stated that receptive and expressive abilities served as protective factors against decline in memory and activity of daily living skills. Vocabulary is a culture-dependent measure. Table 2 shows that in the Vocabulary subtest, our participants could define an average of 10 out of 33 given words. Once they knew a word, they maintained it even until age 60.

This was not the case for Similarities, which demonstrated lower scores in each age cohort compared to the younger age cohort. However, only the 60–69 age cohort demonstrated significantly lower scores compared to age 30–39 in both groups. Rozencwajg and Bertoux (2008) defined Similarities as grouping objects or words according to their common features at a high level of generality and found advantage in Similarities of typical young adults compared to older adults. Thus, although Similarities is considered a crystallised intelligence test, it is sensitive to age in populations with typical development and with intellectual disability (Rozencwajg & Bertoux, 2008).

3.2 | Fluid intelligence

The intriguing findings lie in fluid intelligence. In the general population, fluid intelligence reaches its peak around age 20 and then declines (Góngora et al., 2020; Kaufman, 2001; Rabbitt, 2016). In our study, which started at age 30, both participants with typical development and with intellectual disability demonstrated lower scores in 50–59 and 60–69 compared to the 30–39 and 40–49 age cohorts. In Block Design, participants with typical development demonstrated lower scores at age 50–59 compared to 30–39, whereas in adults with intellectual disability, the lower scores compared to younger age cohorts appeared a decade later, at age 60–69. Thus, neither the hypothesis of accelerated decline in the population with intellectual disability nor the parallel trajectory were supported for fluid intelligence. Participants with intellectual disability exhibited more preserved and moderate decline compared to their peers with typical development.

3.3 | Working and long-term memory

Our findings support those of Kumar et al. (2017) in that the scores of Digit Span Forward/Backward were higher for both participants with typical development and with intellectual disability than the scores in Spatial Span Forward/Backward (the Digit and Spatial Span Forward scores were higher than the Digit and Spatial Span Backward across all age cohorts in both groups). Thus, regarding memory type, there are parallel trends between participants with typical development and with intellectual disability. However, the age trajectories between the two groups differed. Our findings for Digit Span Forward and Spatial Span Backward are in accord with those of Kumar et al. (2017), who found a decline in verbal and visuo-spatial span between ages 40–50 for the population with typical development. Digit Span Forward yielded lower scores in the group with typical development aged 60–69 compared to the younger age cohorts (30–39; 40–49), whereas scores of adults with intellectual disability did not differ significantly across the four age cohorts. Digit Span Backwards demonstrated lower scores in the 50–59 compared to the 30–39 age cohort in both groups. Thus, the Digit Span Backward test is more sensitive to age in both groups. However, findings should be regarded with caution, due to a floor effect of 13% of the participants with intellectual disability. The scores in Spatial Span Forward did not differ significantly along the age cohorts in participants with typical development and with intellectual disability. Spatial Span Backward yielded lower scores in the group with typical development in the 40–49 compared to the 30–39 age cohort, whereas the scores of participants with intellectual disability did not differ significantly across all age cohorts. Again, findings should be regarded with caution, due to a floor effect of 9% of the participants. Thus, individuals with intellectual disability exhibit deficit in Digit Span and Spatial Span Backward. First, the order of presentation plays an important role in determining the performance of individuals with cognitive impairments. Back is more difficult than forward. Furthermore, the Spatial Span Backward is more difficult for individuals with deficit in visuo-spatial tasks than the Forward Span (Donolato et al., 2017).

Long-term memory (Rey-AVLT, Vakil & Blachstein, 1997) yielded lower scores in the total score, in the 40–49, 50–59 and 60–69 compared to the 30–39 age cohorts, and in the 60–69 compared to the 50–59 age cohorts for participants with typical development. Participants with intellectual disability exhibited similar scores across age cohorts. Retention yielded a parallel trend of similar scores across age cohorts in both groups. Thus, as stated above, considering the fact that our study is cross-sectional, we can state, with caution, that adults with intellectual disability exhibited more preserved working and long-term memory skills compared to peers with typical development.

Our findings indicate that contrary to crystallised intelligence which exhibited a parallel trajectory between the groups with typical development and with intellectual disability, fluid intelligence (Matrices and Block Design) and working and long-memory behaved differently and demonstrated more preserved abilities in participants with intellectual disability. This was expressed by similar non-significant differences between the scores (stability) across the age cohorts in Block Design, Digit Span Forward, Spatial Span Backward, and Total Learning in the Rey (Vakil & Blachstein, 1997) in adults with intellectual disability. Adults with typical development exhibited lower scores in older compared to younger age cohorts. These findings of more preserved fluid intelligence and working memory in adults with intellectual disability and greater sensitivity to age in adults with typical development are in line with studies that claim a positive manifold between working memory and fluid intelligence (Kvist & Gustafsson, 2008; Wang et al., 2021). Meta-analyses have demonstrated that working memory and fluid intelligence share around 50%–85% of their latent variance (Kane et al., 2005). It is also documented that fluid intelligence is associated with the *g* general intelligence (Wang et al., 2021). Fluid Intelligence (Gf) is interpreted as the capacity to solve novel, complex problems, using operations such as inductive and deductive reasoning, concept formation, and classification (Horn & Cattell, 1966). General intelligence relates most highly to complex reasoning tasks which suggest that the g-factor involves complex higher-order cognitive processes (Carroll, 1993: Spearman, 1927). Thus, fluid intelligence is associated more with the general intelligence *g* (with different opinions, Horn & Cattell, 1966). The question of correlations between diverse cognitive abilities is beyond the scope of the current study. However, we employed Pearson correlations to shed lights on associations between working memory and fluid intelligence measures in our study groups. The findings indicate similar correlations between fluid intelligence and working memory measures in the two groups. In participants with intellectual disability, Matrix (*Gf*) yielded a significant correlation with Digit Span Backward and Spatial Span Forward ($r = .20–.21$, $p < .05$). Block Design (*Gf*) yielded a significant correlation with Digit Span Backward, Spatial Span Forward and Spatial Span Backward ($r = .20–.43$, $p < .01$). In participants with typical development, Matrix (*Gf*) yielded a significant correlation with Digit Span Backward and Spatial Span Forward ($r = .29–.32$, $p < .05$). Block Design (*Gf*) yielded a significant correlation with Digit Span Backward, Spatial Span Forward and Backward ($r = .25–.46$, $p < .01$). Thus, both groups demonstrated similar correlations between fluid intelligence and working memory measures. Furthermore, the correlations between Block Design and working memory were higher than those between Matrix and working memory. However, both Block Design and working memory measures behaved differently in both groups, with more moderate decline in participants with intellectual disability than in participants with typical development. Our findings indicate that similarly to the typical population, fluid intelligence and memory measures in adults with intellectual disability share a similar construct and are associated more with the *g* which is considered to be a more abstract and complex cognitive task, than with crystallised intelligence. Further research should be conducted to support the association between the crystallised and fluid intelligence and memory and the *g* in the population with intellectual disability.

The more preserved hypothetical trajectory in fluid intelligence and memory in adults with intellectual disability could be attributed to the Cognitive Reserve Theory and late maturation of individuals with intellectual disability. Cognitive reserve refers to a compensatory mechanism that helps people cope with pathological life events such as brain damage or aging. Stern (2012) distinguished between neural reserve and *neural compensation*, where the same brain network may be used differently, or additional brain areas might be recruited. One might argue that individuals with intellectual disability exhibit lower cognitive reserve due to their lower level of intelligence and fewer opportunities for cognitive education and cognitive leisure activities compared to the general population.

However, our study shows a parallel trajectory in crystallised intelligence and a more preserved trajectory in fluid intelligence of adults with intellectual disability compared to adults with typical development. Thus, participants with typical development and with intellectual disability demonstrated more preserved Vocabulary (crystallised intelligence) expressed by similar scores along the four age cohorts beyond the differences in scores between the two groups. In both groups, fluid and working memory measures and Similarities were less preserved than Vocabulary. However, participants with intellectual disability exhibited a more preserved and moderate trajectory than participants with typical development in these domains.

In line with the Cognitive Reserve Theory (2012) and the Compensation Age Theory (Lifshitz, 2020; Lifshitz-Vahav, 2015), we suggest that individuals with intellectual disability are not more vulnerable to accelerated aging than participants with typical development and also exhibit cognitive reserve relative to their level. Support for the Compensation Age Theory in adults with disabilities is also known as the Safeguard Hypothesis (Bathelt et al., 2020). This hypothesis posits that biological processes or differences in cognition, as well as the lifestyle of persons with disability, may protect against age-related decline. For example, Oberman and Pascual-Leone (2014) postulated that cortical hyper-plasticity protects adults with autism spectrum disorders from early onset of Alzheimer disease. A common finding in human functional brain imaging studies is that damage to neural systems paradoxically results in enhanced functional connectivity between network regions, a phenomenon commonly referred to as hyperconnectivity (Hillary & Grafman, 2017). Our study is not a brain study. Nevertheless, our findings could be an indication for the Safeguard Hypothesis in adults with intellectual disability of etiologies other than Down syndrome.

Over the last century, improvements in medical care, nutrition, and public health policy led to an increased life expectancy of adults with intellectual disability, even up to their 70s and 80s (Bayen et al., 2018; Heller & van Heumen, 2021). Even adults with Down syndrome may now experience good health and successful aging, without cognitive deterioration (Krinsky-McHale et al., 2008; Wiseman et al., 2015). In our country, adults with intellectual disability are busy in meaningful activities in employment and satisfying cognitive leisure activities (Lifshitz et al., 2021). Participation in leisure activities holds a potential for improving cognitive functioning and mitigates cognitive deterioration among adults with intellectual disability (Lifshitz-Vahav et al., 2016) and with Down syndrome (Lifshitz et al., 2021). This explanation is speculative, since we did not examine participation in leisure activities. However, the lifestyle of participants with intellectual disability could be indicative of the Safeguard Hypothesis (Bathelt et al., 2020), which might explain the above-mentioned more preserved trajectory.

Another possible explanation is neurological. Brain imaging has demonstrated that brain maturation in the general population appears to peak in late adolescence (Cromer et al., 2015; Crone & Ridderinkhof, 2011). Our previous studies show that intelligence of adults with intellectual disability (age 20–45) was higher than that of adolescents with intellectual disability (age 16–21) with the same basic cognitive level (Chen et al., 2017; Lifshitz et al., 2021). Adults also gained more from mediation aimed to ameliorate cognitive skills than adolescents (Lifshitz et al., 2005, 2011), supporting the Compensation Age Theory in adults with intellectual disability (Lifshitz, 2020).

Based on these studies, it appears that brain maturation in individuals with intellectual disability develops at a slower rate and reaches full maturation in adulthood. Paradoxically, the late brain maturation of adults with intellectual disability may extend their cognitive development period. The trend of slower brain maturation might explain the more moderate decline of participants with intellectual disability compared to peers with typical development. Further brain research is needed to validate this assertion. Chen et al. (2017) found a decline in the Raven Matrices test and Block Design from the 20 to 40 age cohorts among adults with typical development, whereas adults with intellectual disability demonstrated increasing scores between ages 23 and 40 compared to 16–21. Thus, the 'late blooming' trajectory of adults with intellectual disability at ages 20–40 (Chen et al., 2017) compared to adults with typical development turned into a more preserved trajectory and moderate or late decline in older ages.

A further explanation could be the floor effect. As can be seen in the Digit Span Backward and Spatial Span Backwards tests, the scores of the adults with intellectual disability were very low and some of the participants exhibited a floor effect (13% and 9%, respectively). It is therefore possible that they had less to 'lose' over time. It is documented that individuals with intellectual disability exhibit difficulties in Spatial Span (Jarrold & Brock, 2012). The Digit Span Backward and Spatial Span Backward subtests are difficult for adults with intellectual disability and in future research other tests should be used to examine these abilities in this population.

4 | CONCLUSIONS

Our findings indicate four patterns of cognitive performance: (a) Vocabulary (crystallised intelligence), Spatial Span Forward and Retention yielded similar scores across all four age cohorts in participants with typical development and with intellectual disability; (b) Similarities and Raven exhibit lower scores only in the 50–59 or 60–69 compared to the 30–39 age cohort in both groups; (c) Digit Span Forward, and Total Leaning (LTM) yielded lower scores in the 50–59 or 60–69 age cohorts in the typical group, but similar scores in participants with intellectual disability along the age cohorts; (d) Block Design (fluid intelligence) yielded a lower score in the 50–59 cohort versus lower scores only at ages 60–69 in participants with typical development. The Cognitive Reserve Theory, the Safeguard Hypothesis and late maturation might serve as explanations for these findings. Digit Span and Spatial Span Backward are difficult tasks for individuals with intellectual disability.

4.1 | Limitations and recommendations for further research

Our sample included 100 adults with intellectual disability and 83 with typical development. The number of participants in each age cohort ranged between 20 and 28. A small sample size is common in clinical populations such as autism spectrum disorders and intellectual disability due to difficulties in recruiting such adults with special needs, especially in older ages (Lledó et al., 2022). However, it is possible that these participants performed differently from other persons in the same age cohort, which might hinder generalisation. Future research using a larger sample would help validate our findings. There are gender differences in verbal and visuo-spatial memory (Nyberg et al., 2012). However, due to the small sample size in each age cohort, we did not explore gender differences. Further research with a larger sample will enable examination of gender differences. Caffeine or alcohol uptake can affect cognitive functions. However, we have no data on the drinking habits of our participants. In further research, this question should be part of the participants' background characteristics.

Cross-sectional studies in the population with intellectual disability are more frequent, as longitudinal data are difficult to collect from adults with intellectual disability, especially those over 60 (Facon, 2008; McCarron et al., 2022), as some of them may not survive along the waves of the study, especially in older ages. As stated, a cross-sectional design might suffer from a cohort effect (Salthouse, 2019). However, scientists suggest that when typical longitudinal biases are controlled, the results tend to closely resemble those of cross-sectional studies (Kaufman, 2001; Salthouse, 2019). In addition, cross-sectional studies require less time to be set up, and may be considered for preliminary evaluations of association prior to embarking on cumbersome longitudinal-type studies (Caruana et al., 2015). Our hope is that this cross-sectional study will serve as a basis for future longitudinal research. Notably, most standardised tests have 'S' shaped sensitivity curves, where they are more able to discriminate between individuals in the mid-range of scores, and less able to discriminate at both low and high performance levels (Wechsler, 1997b). Lower test sensitivity for the lower performing individuals with intellectual disability would be one explanation of the different trajectories. We administered the WAIS-III[HEB] (Wechsler, 2001) which was translated and validated in Hebrew and is the common test in Israel for assessing the intelligence of adults with typical development. However, the test may not be sufficiently sensitive for individuals with a low cognitive level, such as persons with intellectual disability. This may explain some of the results, especially the floor effect found in Digit and Spatial Span Backward. Future research should use a broad range of cognitive and memory tests adapted for adults with intellectual disability. Our findings relate to aging of adults with typical development and intellectual disability in Israel. Additional cross-cultural comparisons between such populations in other countries are recommended. The level of intelligence of our participants with intellectual disability was at the mild level (IQ = 54–69). Research on cognitive trajectories of participants with lower IQ levels should be conducted.

4.2 | Educational implications

Kim and Kim (2014) differentiated between two types of cognitive interventions aimed at delaying aging in the general population.

'Compensation-focused interventions' are designed to enhance frontal mediating functions or compensate for specific cognitive functions that are adversely affected by aging. Our previous studies showed that adults with intellectual disability (age 20–70; IQ 40–70) can benefit from focused 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 et al., 2010).

In line with the current findings, policy makers and administrators of community residences and vocational centres for adults with intellectual disability should be introduced to the idea of the Cognitive Reserve Theory (Stern, 2012) and the Safeguard Hypothesis (Bathelt et al., 2020). Introduction of cognitive intervention programmes in residential settings for adults and older people with intellectual disability is recommended, together with actions to change attitudes in the staff towards the cognitive modifiability of these residents.

The second type of intervention suggested by Kim and Kim (2014) is called 'stimulation-non focused training' which consists of sensory or non-specific stimulation not directed towards a specific cognitive skill, but which is conducted indirectly through leisure activities. The Cognitive Activity Theory (Marquinea et al., 2012; Wilson & Bennett, 2003) postulates that participation in cognitive leisure activities is associated with current cognitive functioning and with reducing the risk of cognitive decline, which leads to Alzheimer's disease (Wilson & Bennett, 2003). Lifshitz-Vahav et al. (2016) found that participation of adults with intellectual disability with and without Down syndrome contributes to their current cognitive skills and even mitigates the deterioration of their health and adaptive behaviour (Lifshitz et al., 2021). Thus, adults with intellectual disability should be encouraged to participate in leisure activities that involve greater cognitive stimulation as a means to delay and alleviate age-related cognitive deterioration as much as possible. Staff should be guided to use leisure activities to enhance the cognitive literacy of adults with intellectual disability.

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