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Early numerical skills in individuals with Down Syndrome

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Abstract

The aim of the present work was to explore early mathematical competences in individuals with Down Syndrome (DS). Intellectual Disability has been identified as one of the most important features in this population. The behavioral phenotype of individuals with DS is characterized by deficits in cognitive functions and learning abilities. A numerical battery was administered to a group of 11 individuals with DS and 11 Typically Developed (TD) children matched for mental age, as assessed with the Logical Operations Test. The findings revealed that early numerical skills of individuals with DS were well aligned to mental age: the two groups presented similar competences in counting, in mental calculation and cardinality. Moreover, individuals with DS read better Arabic numbers than the control group. Data concerning the discrimination of numbers in individuals with DS was also taken into

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consideration. Certainly, more research on children with DS is needed although the findings here presented have implications to understand the development of numerical skills in DS and to improve the neuropsychological assessment of children with this genetic condition.

Keywords: Intellectual Disabilities; Down Syndrome; Logical thinking; Early numerical skills; Mental age.

1. Introduction

Down Syndrome (DS) is a genetic condition caused by an extra copy of chromosome 21, featuring peculiar somatic traits, a distinctive neurofunctional architecture (Pennington, Moon, Edgin, Stedron, & Nadel, 2003; Edgin, Tooley, Demara, Nyhuis, Anand, & Spanò, 2015) and atypical developmental patterns. DS is the most frequent form of intellectual disability among genetically determined forms (Kittler, Krinsky-McHale, & Devenny, 2008; Parker, Mai, Canfield, Rickard, Wang, Meyer *et al.*, 2010; Daunhauer, Fidler, Hahn, Will, Lee, & Hepburn, 2014). According to the World Health Organization (WHO), DS affects 1 out of every 1.000 - 1.100 living children in the world (WHO, 2015), encompassing different ethnicities and genders. Apart from a poor intellectual functioning, individuals with DS also show compromised cognitive functions as well as impairments in terms of adaptive behavior and learning abilities (Jarrold, Baddeley, & Hewes, 1999; Chapman & Hesketh, 2000; Pennington *et al.*, 2003; Vicari, Marotta, & Carlesimo, 2004; Rowe, Lavender, & Turk, 2006; Iacono, Torr, & Wong, 2010; Lanfranchi, Jerman, Dal Pont, Alberti, & Vianello, 2010; Lee, Fidler, Blakely-Smith, Daunhauer, Robinson, & Hepburn, 2011; APA, 2013). Although the literature describes the typical features of individuals with DS, the interaction between epigenetic, environmental and chromosomic variables triggers a series of individual differences, on a genetic, neurofunctional and cognitive level, which can lead to very different neuropsychological profiles (Vianello, 2006; Karmiloff-Smith, Al-Janabi, D'Souza, Groet, Massand, Mok *et al.*, 2016). In spite of the fact that intellectual disability is currently and usually identified as one of the most important characteristics of individuals with DS (Vicari, Bellucci, & Carlesimo, 2005; Contestabile, Benfenati, & Gasparini, 2010), only a handful of studies have globally analyzed the degree of intelligence in this population of individuals. More in general, the peak of intellectual functioning of individuals with DS is comparable to that of a 7-year-old child: a mental age (MA) beyond 7 years old has been demonstrated only in very few studies, even in adult subjects (Dykens, Hodapp, & Finucane, 2000). Researches revealed that Intellectual Disability might vary from mild to severe in this population (e.g.: Määttä, Kaski, Taanila, Keinänen-Kiukaanniemi, & Iivanainen, 2006; Vianello, 2006; Contestabile *et al.*, 2010; Lott & Dierssen, 2010; Orsini, Pezzuti, & Picone, 2012; Grieco, Pulsifer, Selingsohn, Skotko, & Schwart, 2015). These conflicting results are also due to discussed methodological issues, concerning the neuropsychological assessment of individuals with intellectual disabilities (Vicari, 2004; Vianello, 2006; Edgin, Mason, Allman, Capone, DeLeon, Maslen *et al.*, 2010; Patterson, Rapsey, & Glue, 2013; Pulina, Vianello, & Lanfranchi, 2019). There are various national and international scientific studies concerning the intellectual functioning of individuals with DS; many authors administered psychometric instruments based on intelligence as constructs of a factor analysis, while few studies actually focused their attention on the quality of thinking of children with DS.

By employing tools based on the Piagetian theory, Moniga (2007) and Pizzoli and colleagues (Pizzoli, Lami, & Stella, 2001) analyzed the sensorimotor competences of children with DS during the first three years of their lives. Vianello and co-workers (Vianello, Lanfranchi, & Moalli, 2006) analyzed the logical operations of 189 children, aged between 8 and 17, using the Logical Operations Test (Vianello & Marin, 1997). The authors found that the mental ages of these individuals varied from 4 years and 10 months to 5 years and 7 months and they were able to successfully solve logical operations at a double chronological age (CA) compared to their TD counterparts (Vianello *et al.*, 2006). It has been demonstrated that logical operations are associated, even in non-typically developing children, to subsequent mathematical skills (Van de Rijt & Van Luit, 1998). Some studies reported that subjects with DS show difficulties in logical operations and in numerical cognition, exhibiting a delay of about two years in this domain compared to other learning abilities (Gelman & Cohen, 1988; Porter, 1999; Nye, Fluck, & Buckely, 2001; Buckley, 2007). Math performances of individuals with DS would seem to be inferior to their reading and writing performances and they generally do not meet 2nd-grade school requirements (Rynders, 1999). Through the CA-MT test (Cornoldi, Lucangeli, & Bellina, 2002), Sestili and collaborators (Sestili, Moalli, & Vianello, 2006) observed lower numerical skills in individuals with DS, as opposed to those of TD children at the beginning of the primary school. Scientific studies on the numerical cognition in DS are limited and, therefore, require further research, given the impact that mathematical skills have on each individual’s daily life activities and personal autonomy. Subjects with DS thus present severe difficulties in mathematical learning, vulnerabilities that are not directly ascribable to the child’s general functioning (Marotta, Viezzoli, & Vicari, 2006). Authors observed a significant gap in mathematical skills between children with DS and TD children of the same chronological age (Brigstocke, Hulme, & Nye, 2008), in particular in numerical knowledge, in counting and calculation (Porter, 1999; Nye *et al*., 2001). The origin of these difficulties is a debated topic. Some researchers support the *developmental hypothesis* (Zigler, 1969), suggesting that the mathematical difficulties of individuals with DS stem from their low general cognitive level (e.g., Caycho, Gunn, & Siegal, 1991). Others support the *difference hypothesis* (e.g., Gelman & Cohen, 1988; Nye *et al*., 2001) by showing poorer performance of individuals with DS in comparison to TD children of the same mental age. Sella and co-workers (Sella, Lanfranchi, & Zorzi, 2013) investigated the numerical estimation in children with DS. They compared a group of 21 participants with DS (M_{age} 14 years and 2 months) to two control groups of TD children, matched for verbal MA (Peabody Picture Vocabulary Scale-Revised – PPVT-R; Dunn & Dunn, 1997; M_{MA} = 5;4, SD_{MA} = 0;6 months) and CA. The children with DS showed a specific deficit (even after accounting for MA), which emerged when they had to distinguish between small numbers, up to 4 (and particularly when comparing 2 and 3, or 3 and 4). The discrimination between larger number sets was similar between the DS group and the control group of similar MA. Considering the two core systems responsible for numerical skills, the *approximate number system* (ANS) and the *object tracking system* (OTS), the authors suggested that the OTS was compromised in subjects with DS, while the ANS, and thus their ability to compare large number sets, seemed to be in line with the MA. Other studies supported these findings: using the *preferential looking* paradigm, Paterson and colleagues showed a deficit in the discrimination of two or three objects in a sample of 30-month mentally-aged children (Paterson, Girelli, Butterworth, & Karmiloff-Smith, 2006). The OTS system, but not the ANS, evaluated with the test of Molin and co-workers (Molin, Poli, & Lucangeli, 2007), correlated with numerical cognition in individuals with DS and TD-MA children (Sella *et al*., 2013). Following these authors, other studies were also in support of an non-compromised ANS system in children with DS: children with DS from 5 to 8 years of age could discriminate between large number sets and they were more competent when the ratio (the difference) between the two sets was significantly large, as in TD subjects (Izard, Sann, Spelke, & Streri, 2009). They also showed some difficulties in tasks concerning dots discrimination with a 2:3 dot ratio (Camos, 2009; Abreu-Mendoza & Arias-Trejo, 2015). The debate of a similarity in the ANS system between individuals with DS and subjects with TD-MA or TD-CA remains open. Lanfranchi and colleagues also administered numerical estimation tasks (number-to-position with interval: 1-10 and 1-100) to a group of adolescents with DS (Lanfranchi, Berteletti, Torrisi, Vianello, &

Zorzi, 2015). The performances on these tasks were similar between the group of DS and TD-MA children.

Furthermore, the development of preverbal numerical skills to more complex ones, related to linguistical and socio-cultural aspects (Geary, 1994, 2000), could be difficult for children with DS too. In 1986, Gelman and Gallistel registered lower performances in counting and cardinality tasks in individuals with DS compared to pre-schooler subjects having the same MA. Caycho and colleagues showed competences in cardinality tasks in this population also with sufficient linguistical skills (Caycho *et al.*, 1991). Through the "*give-a-number*" task, Nye and collaborators (2001) found that only a third of the participants with DS was able to use the cardinality's principle, while other authors argued that the latter competence is in line with the MA (Bashash, Outhred, & Bochner, 2003; Sella *et al.*, 2013). Some authors investigated the other two counting principles in the population with DS: they were able to use the one-on-one correspondence and the stable order principles (Caycho *et al*., 1991; Bashash *et al*., 2003). Sella and collaborators described counting as less fluent in individuals with DS compared to TD subjects (Sella *et al.*, 2013). In this respect, the analysis of Abdelahmeed (2007) on DS' counting competences showed severe difficulties in this domain but also emphasized the important role of interventions. Gelman and Cohen (1988) recognized counting issues in the population with DS and, according to several authors, this is restricted to procedural counting. It would seem that subjects with DS are not aware of their errors in the counting sequences: they tend to forget number-words and/or omit words or objects during enumeration (Porter, 1999). In 1974, Cornwell noticed children with DS were not able to complete their tasks when they interrupted the sequences, or they needed to restart counting from the very beginning. This was probably due to rote learning. Hanrahan and Newman (1996) also claimed that children with DS master counting and recognition of numbers from 1 to 10 through mere repetition. Finally, Nye and colleagues found that children with DS showed shorter counting sequences and could enumerate fewer objects than TD-MA children (Nye *et al.*, 2001). Some authors found severe difficulties in the calculation process in children with DS as well (Marotta *et al*., 2006). Hence, there is substantial evidence on neuropsychological deficits in individuals with DS; however, findings in some domains, such as numerical cognition, remain unclear.

2. Aims and hypothesis

The main purpose of the present study was to analyze the early numerical competences in individuals with DS and to compare them to the MA-matched TD group, to identify strengths and weaknesses in counting, calculation and lexical and semantic processes concerning the MA, as evaluated with the Logical Operations Test – OL18 (Vianello & Marin, 1997). We hypothesized that subjects belonging to different populations but of equal mental age show the same skills in all of the numerical tasks under examination. The question addressed was whether the numerical competences displayed by individuals with DS were tied to the overall cognitive level (indexed by mental age) or whether these individuals showed specific deficits even concerning the MA.

3. Methods

3.1. Sample

The participants recruited in the study were eleven subjects with DS (6 males, 5 females) with a mean CA of 10 years and 4 months (*SD* = 4.3 years; age range = 5 years and 7 months to 17 years and 11 months) and with a mean MA of 4 years and 6 months (*SD* = 4 months; age range: 48 to 59 months; see Tab. 1 for more details). All our participants were Italian native speakers and were still attending school and all of them were included in regular schools. The selection criteria were the following: a MA between 48 and 59 months, a CA between 5 and 17.11 years and the absence of hearing problems. Subjects with DS and with a MA lower than 48 months or higher than 59 months were thus excluded from the study sample (*n* = 8). Concerning the overall socioeconomic status (SES), as estimated from parents' highest level of educational attainment, we found that 7 (64%) mothers and 8 (73%) fathers had a middle/low level of education (they had completed high school or at least a form of basic education), while 4 (36%) mothers and 3 (27%) fathers had a high educational level (they had completed a Bachelor/Master's degree). The mean age of the mothers at the time of their offspring's birth was 40 (*SD* = 5, age range = 33-50). The mean age of the fathers at the time of their offspring's birth was 41 (*SD* = 4, age range = 36-50; refer to Tab. 1 for more details).

A control group of typically developed children was recruited and they were matched for mental age to the DS group. The TD-MA group was comprised of eleven TD children (6 males, 5 females) with a mean CA of 4 years and 5 months (*SD* = 3 months; age range = 4 years and 2 months to 4 years and 9 months) and with a mean MA of 4 years and 6 months (*SD* = 4 months; age range = 48 to 59 months; see Tab. 1 for more details). All participants were Italian native speakers, attending the second year of the Republic of San Marino's kindergartens (RSM). The selection criteria were the following: the absence of certified disabilities, a Fluid Reasoning Index (FRI), as measured by the Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (WPPSI-IV), scoring higher than 70 (Wechsler, 2012; Saggino, Stella, & Vio, 2019) and a CA between 4 and 4.11 years. Concerning the overall socioeconomic status (SES), as estimated from parents' highest level of educational attainment, we found that 5 (45.5%) mothers and 8 (73%) fathers had a middle/low level of education (they had completed high school or at least a form of basic education), while 6 (54.5%) mothers and 3 (27%) fathers had a high educational level (they had completed a Bachelor/Master's degree). The mean age of the mothers at the time of their offspring's birth was 31 (*SD* = 4, age range = 24-36). The mean age of the fathers at the time of their offspring's birth was 34 (*SD* = 5, age range = 25-39; see Tab. 1 for more details).

These two groups differed significantly on CA [$t(20) = -5.854$, $p < .001$] and on parents' CA [mother, $t(19) = -4.448$, $p < .001$; father, $t(18) = -3.368$, $p = .03$]. The two groups did not differ significantly on the parents' educational level [father, $x^2(1, N = 20) = .808$, $p = .59$; mother x^2 $(1, N = 22) = .733$, $p = .39$].

Table 1 – *Socio-demographic characteristics of the TD-MA and DS groups*

			TD-MA	DS
			n = 11	*n = 11*
Infant's gender	Male Female	*N (%)*	6 (60) 5 (40)	6 (60) 5 (40)
Infant's age (years)		*M (SD); range*	4.5 (0.3); 4.2-4.9	10.4 (4.3); 5.7-17.11
Maternal age (years)		*M (SD); range*	31 (4); 24-36	40 (5); 33-50
Maternal education	Low/medium High	*N (%)*	5 (45.5) 6 (54.5)	7 (64) 4 (36)
Paternal age (years)		*M (SD); range*	34 (5); 25-39	41 (4); 36-50
Paternal education	Low/medium High	*N (%)*	8 (73) 3 (27)	8 (73) 1 (9)

A pairing criterion by gender and mental age was chosen for the purpose of this study. Groups were individually matched on gender and on MA, as assessed by the OL18 (Vianello & Marin, 1997). The test, based on Piaget's cognitive theory, is comprised of 18 tasks that assess areas of logical thinking, such as seriation, numeration, and classification. Each group's MA mean was 4 years and 6 months (*SD* = 4 months; range: 48 to 59 months). There weren't statistically significant differences between the two groups [seriation: $U = 55.50$, $z = -.36$, $p = .75$, $r = -.08$; numeration: $U = 71$, $z = .73$, $p = .52$, $r = .15$; classification: $U = 55$, $z = -.61$, $p = .75$, $r = -.13$].

Moreover, in order to also have a measure of fluid intelligence, the recent WPPSI-IV (Wechsler, 2012; Saggino *et al.*, 2019) was administered to both the DS and TD-MA groups. The raw scores of the DS and TD-MA groups to both tests are presented in Table 2. There weren't statistically significant differences between the two groups (see Tab. 2 for details).

The participants to this survey were children and this study was conducted in compliance with the WMA Declaration of Helsinki's latest revision. Parental consent forms describing the project's objectives, the research procedures followed as well as information concerning data retrieval were presented to the parents and obtained before testing.

Table 2 – *Fluid intelligence (WPPSI-IV FRI): comparison between the TD-MA and DS groups*

	TD-MA		DS		Mann-Whitney			
WPPSI-IV variables	*M (SD)*	*Mdn*	*M (SD)*	*Mdn*	*U*	*z*	*p*	*r*
Matrix Reasoning	10.91 (3.08)	11	9.54 (4.32)	10	50	-.69	.52	-.15
Picture Concepts	8.27 (3.52)	8	6.10 (4.53)	7	48	-.82	.44	-.17
FRI	19.18 (4.58)	18	16.45 (7.95)	17	44.50	-1.06	.30	-.23

3.2. Instruments

The tools described in the following section were appropriate for our sample of individuals with DS because the average mental age was 5 years old.

3.2.1. The Numerical Intelligence Scale for children aged between 4 and 6 – BIN 4-6 (Molin et al., 2007)

It provides a measurement of numerical and counting skills. It provides specific indexes for each area investigated, and specifically the lexical, counting and semantic processes.

Lexical tasks assess the knowledge of the names of numbers and of the stable sequence of numbers. In Arabic numeral reading, the child must say the name of the number presented, which is shown in Arabic numerals. In Arabic number recognition, the child must recognize and choose the Arabic-coded number (one among three), which has been pronounced by the examiner. In the correspondence between the Arabic number and quantity, the child must specify the exact quantity of dots corresponding to the Arabic number presented. A point is attributed to each correct item. In each task, the minimum score is 0 and the maximum score is 9.

Counting tasks assess the ability to count (i.e. counting 1-20: the child must count out loud from 1 to 20 using the correct sequence). The minimum score is 0 and the maximum score is 20. Errors are recorded and then subtracted from the total scoring. The total time (in seconds) is also recorded.

Semantic tasks assess the ability to understand the link between numbers and their quantity representations. In the discrimination of dots, the child must choose which set contains more dots from a two-piece set. There are 10 difficulty-scalable items, which include comparisons between dot sets spanning different sizes (congruent and incongruent situation) and same size set comparisons (neutral situation). A point is attributed to each correct item. In each task, the minimum score is 0 and the maximum score is 10. The total time (in seconds) is also recorded.

3.2.2. Counting (1-10)

The child must count out loud from 1 to 10 in the correct sequence. A point is attributed to each correct number. The minimum score is 0 and the maximum score is 10. The total time (in seconds) is also recorded.

3.2.3. Backward counting (5-1)

The child must count out loud from 5 to 1 in the correct sequence. The classic “5, 4, …” example is given to get the child started. A point is attributed to each correct number located in the correct backward sequence. In the case of the repetition of the suggested sequence (5, 4), the attributed score is equals to zero.

3.2.4. Number Sense: Prerequisites – SNUP (Tobia, Bonifacci, & Marzocchi, 2017)

It assesses early numeracy skills and can be administered to children from 4 to 6.9 years old. The *Quantity Comparison Test* comprises 24 items, divided into two separate subtests, evaluating simple stimuli quantity comparison and complex stimuli quantity comparison, respectively. In this test, children are asked to quickly indicate the box with a greater number of elements, choosing between two illustrated baskets of fruit. The number of elements varies from 3 to 20, and the differences between sets are from 1 to 6 units. A point is attributed to each correct item. The minimum score is 0 and the maximum score is 24.

3.2.5. "Give-a-number" task (ad hoc, based on Wynn's model, 1990, 1992)

The child has 10 tiny pale wooden cubes, measuring 2 × 2 × 2 cm each, and a small transparent box, measuring 5 × 15,5 × 9 cm, in front of him. He/she is asked to put an ever-changing number of cubes in the small box (e.g.: "*Put two cubes in the box*") and to say "done/finished" when his/her assignment is completed (meanwhile the operator covers his/her eyes). An example item is provided. Quantities are exposed in the following order: 2-, 6-, 9-, 4-, 3-, 7-, 1-, 5-, and 8-. A point is attributed to each correct item. The minimum score is 0 and the maximum score is 9.

3.2.6. Mental calculations < 5 task (ad hoc)

The child must answer 4 simple additions orally proposed by the examiner. The experimental items include the calculations 1+1=2; 3+1=4; 1+2=3 and 2+2=4. Children are allowed to answer verbally or to show the result with their fingers. A point is attributed to each correct item. The minimum score is 0 and the maximum score is 4.

3.2.7. WPPSI – Wechsler Preschool and Primary Scale of Intelligence – Fourth Edition (Wechsler, 2012; Saggino et al., 2019)

The WPPSI-IV is an innovative measure of cognitive development for preschoolers and young children. The WPPSI-IV model reflects contemporary structural theories, such as the CHC (Cattell-Horn-Carroll) theory. *Matrix Reasoning* (MR) and *Picture Concepts* (PC) are administered to the participants. Every single subtest provides a raw score (MR range: 0-26; PC range: 0-27) and, given the sum of the two subtests' weighed scores, it is possible to obtain a composite score, the FRI with a mean value of 100

(*SD* = 15). The FRI may be conceptualized as measuring fluid and inductive reasoning, broad visual intelligence, simultaneous processing, conceptual thinking, and classification ability. We referred to the manual for the method of administration and scoring.

3.2.8. Logical Operations Test – OL 18 (Vianello & Marin, 1997)

It assesses the development of logical thinking. The test, based on the Piagetian cognitive theory, is comprised of 18 tasks that assess areas of logical thinking, such as seriation, numeration, and classification. The test is standardized for the Italian population aged between 4 and 9. A score of 1 is given for each task performed correctly. The grand scoring total is hence 18. This raw score can then be turned into a mental age score. This test seems particularly appropriate to match children with DS with TD children on a central intelligence component while limiting the influence of culture and linguistical ability (for a review, see Vianello & Marin, 1997).

4. Procedure

Participants of the DS group were contacted through several associations for people with DS in Emilia Romagna (Italy) and the Republic of San Marino (RSM). Participants of the TD-MA group were contacted in some kindergartens of the Republic of San Marino (RSM) during the 2018-2019 term. All participants were exposed to areas of logical thinking, fluid non-verbal reasoning, and early numerical competences. All the tasks were administered individually in two sessions, separated by approximately 1 week, with each session lasting approximately 30 minutes. Each session was performed in a well-lit and quiet room.

5. Data analysis

All statistical analyses were carried out using SPSS 22.0 for Windows with alpha = .05. The experimental design involved two groups, a TD-MA and a DS group, at a data collection moment (t0). Prior to conducting analyses, data was checked for violation of assumptions using the Kolmogorov-Smirnov test. Because distributions for some of the communicative behaviors were non-normal, nonparametric Mann-Whitney tests were conducted to assess potential differences in early numerical competences between the DS and TD-MA groups. Effect sizes (r) for Mann-Whitney U tests were calculated using the formula $r = \frac{Z}{\sqrt{N}}$, in which *z* is *z*-

the score that SPSS produces and *N* is the size of the study on which *z* is based. The standard values of *r* for medium and large effect sizes are .3 and .5, respectively (Field, 2018).

Raw scores for the DS and TD-MA children in early numerical competence tests are shown in Table 3.

5.1. Lexical process

Individuals with DS showed a significantly higher score in the Arabic numbers reading task: they were more accurate than the children of the TD-MA group. The other numerical lexical task did not differ in the two groups, although individuals with DS showed a higher performance in the recognition of Arabic numbers. The participants could also associate about 5 out of 9 Arabic numbers to their numerosities: the total scores did not significantly differ in the two groups (see Mann-Whitney test in Tab. 3).

5.2. Mental calculations

The performances of a simple additions task did not differ in the two groups, although the *p*-value was near significance (p = .06; see Mann-Whitney test in Tab. 3). The percentage of children of the TD-MA group (36%) who completed at least one mental additive operation was lower than the DS group percentage (64%) but differences between the two groups were not statistically significant [$x^2(1, N = 22) = 1.64$, $p = .20$].

5.3. Counting

The performances of counting did not differ in the two groups, although the children of the TD-MA group were more accurate than the individuals of the DS group. Moreover, the TD-MA group was significantly quicker in counting from 1 to 10 compared to the DS group (p = .02; see Mann-Whitney test in Tab. 3). In order to control this data, the same analysis was conducted a second time only selecting the participants who were able to correctly count from 1 to 10 (n = 14) and from 1 to 20 (n = 10): the TD-MA group confirmed to be quicker than the DS group also in this particular case but the difference was not statistically significant. The scores for the backward counting test did not significantly differ in the two groups (refer to Tab. 3 for more details).

5.4. Semantic processes

Although individuals with DS showed a lower accuracy and time scores in the BIN 4-6 task (Molin *et al*., 2007), the performance for the dot comparison task did not significantly differ in the two groups. Instead, there were significant differences in the quantity test (SNUP; Tobia *et al*., 2017), particularly on a basic quantity comparison subtest (same-sized element sets). Individuals with DS showed, in fact, a significantly lower score in this task: they were less accurate than the children of the TD-MA group (p = .04; see Mann-Whitney test in Tab. 3). Finally, the performances in the *give-a-number*" task showed that participants could identify the cardinality of about 5 out of 9 numbers (mean): the total scores did not significantly differ in the two groups (see Mann-Whitney test in Tab. 3).

Table 3 – *Early numerical skills: comparison between the TD-MA and DS groups*

	TD-MA		DS		Mann-Whitney			
Variables	*M (SD)*	*Mdn*	*M (SD)*	*Mdn*	*U*	*z*	*p*	*r*
Numbers reading	5.27 (2.90)	6	7.91 (1.92)	9	96.50	2.45	**.02**	.52
Numbers recognition	7.18 (2.14)	8	8.64 (.67)	9	83.50	1.70	.13	.36
Numbers-quantities correspondence	5.27 (1.79)	5	5.82 (1.40)	5	69.50	.61	.56	.13
Mental additions < 5	.45 (.69)	0	2 (1.79)	2	89.50	2.05	.06	.44
Counting 1-20 (accuracy)	17.91 (2.16)	19	14.64 (5.87)	16	43.00	-1.18	.27	-.25
Counting 1-20 (seconds)	14.82 (6.26)	13	23 (19.21)	17	76.50	1.05	.30	.22
Counting 1-20 (seconds) (n = 10)	15.83 (7.47)	14	28.5 (29.08)	15	14.5	.53	.61	.17
Counting 1-10 (accuracy)	10 (0)	10	9 (1.90)	10	38.50	-2.15	.15	-.46
Counting 1-10 (seconds)	5.09 (2.74)	3	11.73 (8.89)	10	96.50	2.38	**.02**	.51
Counting 1-10 (seconds) (n = 14)	5.14 (3.08)	3	7.28 (4.31)	5	34.00	1.23	.26	.33
Counting 5-1 (accuracy)	2.27 (2.61)	0	2.73 (2.61)	5	66.00	.42	.75	.09

Dot discriminations (accuracy)	8.36 (1.12)	8	7 (1.79)	7	34.50	-1.75	.08	-.37
Dot discriminations (seconds) (*n* = 20)	19.70 (15.72)	12.5	18.30 (4.88)	17	70.50	1.56	.12	.35
Quantity Comparison (accuracy)	20.45 (2.16)	21	18.18 (3.03)	18	29.50	-2.05	**.04**	-.44
Give-a-number task	5 (2.19)	5	5.64 (2.84)	7	68.50	.53	.61	.11

6. Discussion

The present work was aimed at analyzing the early numerical competences in individuals with DS. The participants in our study did not show an understanding of the reversibility concept. They presented irreversible mental representations, which are typical of the pre-operational stage. Participants with DS were indeed able to perform the one-to-one correspondence tasks, as has already been noted in this population by Caycho and colleagues (1991), but, in our case, only one subject out of two was able to use it as a strategy to infer numbers that were no longer visible. No subject with DS was able to understand that, when something changes in number or appearance, it is still the same, a concept known as conservation. They were not capable to dissociate spatial information from number-related information, showing they did not acquire awareness that actions can be reversed. In this study, individuals with DS and TD children presented similar prelogical operations. Our results show that the performances of individuals with DS on numerical tasks were well aligned with that of TD children matched for MA. DS and TD-MA groups did not differ on most tasks of numerical cognition: they indeed presented similar competences in counting, in mental calculation and cardinality. Concerning the latter skill, the performances of individuals with DS paralleled that of TD-MA children: all participants were able to identify the number's cardinality of a restricted number of objects (about 5 out of 9), confirming the same results reached by other authors (Caycho *et al*., 1991; Bashash *et al*., 2003; Sella *et al*., 2013). Likewise, our results revealed that all the participants of the sample showed difficulties in a verbal calculation task. Lanfranchi and colleagues (Lanfranchi *et al*., 2010; Lanfranchi, Baddeley, Gathercole, & Vianello, 2012) claimed that some problems with mental operations could be due to deficits in other functions, like working memory and attention, which are both considered important for the numerical development. As regards counting, Abdelahmeed's review (2007) described the presence of significant difficulties in this area in individuals with DS. Our results were in line with previous research by Porter (1999) and revealed that participants with DS completed the sequences of counting as TD-MA children, but they made a greater number of errors and omissions. Therefore, the performances of individuals with DS on forward and backward counting, both in terms of accuracy and time, were well aligned with that of the TD-MA group. Some authors have recently analyzed the ANS and OTS systems in the DS population and have underlined, in particular, a deficit in the latter (Paterson *et al*., 2006; Sella *et al*., 2013). The present study also investigated the ANS system, through two quantity comparison tasks; the results show that dots discrimination competences of individuals with DS were well aligned to those of TD children matched for MA. Indeed, the scores in the dot discrimination task of the BIN 4-6 test (Molin *et al.*, 2007) did not show significant differences in the ANS between both groups. Nevertheless, we noted that subjects with DS performed more errors when they were asked to discriminate between two sets of dots and when there was inconsistency between the number of dots and the size of dots (e.g.: the set with the greater number of dots is composed of smaller dots) compared to the TD-MA group. We also noticed that the performances of participants were different by changing the presentation materials, namely by exposing subjects to an objects comparison task instead of a dot comparison task. Individuals with DS performed worse than TD-MA children in the quantity comparison test, in which they had to indicate the group with a greater number of elements, choosing between two illustrated baskets of fruit. In this test (SNUP; Tobia *et al*., 2017), quantity discrimination in individuals with DS did not appear to be in line with mental age. In this respect, our data was in line with previous studies (Camos, 2009; Sella *et al.*, 2013; Abreu-Mendoza & Arias-Trejo, 2015): more research is needed but our results indicate that the ability to discriminate large non-symbolic numerosities in individuals with DS could be in line with the mental age, although it could be sensible to visual stimuli properties. Finally, we noted that the lexical knowledge of numbers was more developed in participants with DS than in TD-MA children. More specifically, we found that the clinical group performed significantly better than TD-MA children in the Arabic numbers reading task. The latter result could be a positive consequence of the longer exposure to the numbers due to their years of education and CA ("*experience effect*", Fidler, Daunhauer, Will, & Schworer, 2018).

In sum, the present study reveals that early numerical competences of individuals with DS were well aligned to mental age, measured by a logical thinking test: they can recognize numbers and associate them to their corresponding quantity, count from 1 to 20 and from 5 to 1 and they are sufficiently competent in using the cardinality principle. They are stronger in Arabic number reading, while we found inconsistent data concerning numerosity discrimination, leaving the debate still open.

More research is needed that would involve more individuals with DS: one limitation of this study was its small sample size. According to Edgin and colleagues (2010), there are some issues to consider when assessing the cognitive abilities of individuals with DS. As underlined by Pulina and colleagues (2019), some tasks may be too difficult for individuals with DS (*floor effect*). Moreover, the instruments generally used in research and clinical practices are standardized on TD individuals: they do not allow comparing results with normative data. Another issue could be linked to the *experience effect* (Fidler *et al.*, 2018): the scores of participants with DS could be a positive consequence of the environment ("*experience effect*"). The limitations and strengths of the current study lend themselves to several future research directions. It could be interesting to compare a group of children with DS and a group of TD with the same CA. It could also be interesting to monitor participants longitudinally with the purpose of analyzing predictive factors of numerical skills in atypical development. Moreover, it could also be useful to include different age groups or populations (i.e.: Williams Syndrome) and/or to compare performances of 4-year-old children with those of adolescents with DS, to understand the influence of education and environmental context on numerical cognition.

In conclusion, these results have implications to understand the development of numerical skills in individuals with DS. Moreover, the present findings suggest that numerical cognition and logical thinking should also be included in the assessment of the numerical skills of children with DS. During testing and evaluation, clinicians should use tools to analyze fluid reasoning (e.g.: IQ score) and the mental structures (e.g.: logical thinking). The mental age is a very important data in neuropsychological practices to underline the main strengths and weaknesses in each cognitive profile. Starting from these points, it is possible to plan and carry out neuropsychological interventions for most of the weaknesses. Moreover, projects of inclusion and well-being in both school and daily life could promote the main strengths in individuals with DS.

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