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Exploring the effect of numerical video training on at-risk preschool children

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A R T I C L E I N F O

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A B S T R A C T

Evidence has shown the importance of early numerical skills in sustaining future mathematical abilities. However, the literature has largely ignored the potential of educational videos to improve numerical abilities in children at risk of developing numeracy difficulties. The aim of the present study was to examine the effectiveness of a numerical video training on domain-specific precursors in first-year preschoolers ($Mean_{age} = 43.64$ months) by comparing two intervention groups (i.e., at-risk of developing numeracy difficulties group; average intervention group) with an active control group, while controlling for domain-general precursors. Results revealed that the training was effective in enhancing counting skills in both the at-risk and average intervention groups. The findings also showed an enhancement of cardinality knowledge and digit recognition in the delayed post-test, but only for the group with average numerical abilities. Results will be discussed considering the implications for children who are at risk of experiencing numerical difficulties.

Introduction

Despite the growing trend of the "mathematization of society" (Gellert & Jablonka, 2007), studies have shown that one in five students demonstrate poor numerical skills and between 4 and 14 % of children and adolescents show a pronounced difficulty in mathematics (Barbaresi et al., 2005; Butterworth, 2011; Cornoldi & Zaccaria, 2014; Dowker, 2004; Shalev, 2007; Shalev et al., 2005). Furthermore, the phenomenon was exacerbated and chronicled by the documented learning loss due to the closure of schools to contain the spread of the Covid-19 pandemic (for a meta-analysis see Betthäuser et al., 2023). In view of the critical situation of mathematics learning against the background of society's increasing 'dependence' on numbers (Foley et al., 2017; Gerardi et al., 2013; Gross et al., 2009; Peterson et al., 2011), difficulties in the numerical and mathematics domains can act as a filter, thus reducing an individual's chances of success, particularly at the beginning of the learning process.

The current study sought to evaluate the effectiveness of a video-based intervention in fostering preschoolers' domain-specific skills, defined as specific abilities that predict formal mathematics learning in primary school (Geary et al., 2018; Morgan et al., 2011; Nguyen et al., 2016). In doing so, we aim to control for domain-general abilities (i.e., working memory, attention), which are cognitive abilities that transversally sustain the development of different learning domains (Cragg & Gilmore, 2014; Passolunghi et al., 2015). We have also considered a sample of first year preschoolers at risk of developing numerical difficulties that, in the literature, are indicated as children that show underachievement in numerical skills (Aunio et al., 2021; Bryant et al., 2021; Morgan et al., 2009), posing a risk for later formal mathematics learning (Morgan et al., 2011). In this context, few interventions have been conducted considering children at risk of developing numerical difficulties (e.g., Aunio et al., 2021; Clarke et al., 2016; Van Herwegen et al., 2017), especially considering first-year preschoolers. Furthermore, we focused on testing a video-based intervention that, in our study, consists of passively exposing children to videos with numerical content (Cuder et al., 2022; Mares & Pan, 2013). There is a paucity of research exploring the use of numerical videos to enhance children's numerical skills, despite the rising popularity of videos among preschoolers (Marsh et al., 2019; Rideout & Robb, 2017). The present study aims to bring novel insights to the effectiveness of video-based interventions in promoting numerical skills in first year preschoolers ($Mean_{age} = 43.64$ months) at risk of developing numerical difficulties. These findings would have useful implications for policymakers and education professionals operating in educationally deprived contexts by

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providing them with new tools and methods to support equity in learning.

Precursors of mathematics learning

Mathematics learning is a cumulative process in which the acquisition of domain-general and -specific precursors is crucial to supporting future formal learning (Bodovski & Farkas, 2007; Nelson & Powell, 2018). However, evidence shows that differences between children in precursors tend to exacerbate over time, increasing the risk of developing marked mathematics difficulties (Morgan et al., 2011; Nelson & Powell, 2018). Literature has shown that it is possible to identify children who are at risk of developing numerical difficulties as early as preschool age (Duncan et al., 2020; Fitzpatrick et al., 2020). Studies agree that children at risk of developing numerical difficulties usually exhibit moderate weakness that tends to persist over time (Murphy et al., 2007; Zhang et al., 2020). Commonly, intervention studies identify children at risk of developing numerical difficulties by considering performance under a specific cutoff that, for the preschool population, can range from the 25th to the 50th percentile (Aunio et al., 2021; Toll & Van Luit, 2012). In this context, literature highlights that weaknesses in specific domain-general and domain-specific precursors may influence formal mathematics learning, necessitating the implementation of tailored interventional studies.

Domain-general cognitive precursors

The literature has amply demonstrated that domain-general cognitive skills are a necessary scaffold for the early development of mathematics competence (Clark et al., 2014; Cragg & Gilmore, 2014; Passolunghi et al., 2015). Verbal intelligence, measured as vocabulary skills, supports preschool children's mathematics learning both directly and indirectly by facilitating children's ability to access symbolic numerical information, which in turn can support subsequent mathematics competence (Gray & Reeve, 2016; LeFevre et al., 2010).

In addition, Working Memory (WM), a cognitive system of limited capacity that allows the temporary storage and active manipulation or processing of information while performing a cognitive task (Baddeley, 1986; Miyake & Shah, 1999; Raghubar et al., 2010), has shown a strong relationship with mathematics competence already at preschool age and later throughout formal schooling (Passolunghi et al., 2015; Szűcs et al., 2014). In this regard, evidence suggests that working memory supports the development of various domain-specific precursors (Ashkenazi & Shapira, 2017; De Vita et al., 2021), influencing how children use strategies and form numerical representations (Crollen & Noël, 2015; Dupont-Boime & Thevenot, 2018).

Also included among the domain-general precursors of mathematics learning is selective attention (Lane & Pearson, 1982; Posner & Petersen, 1990), defined in the literature as the capacity that allows an individual to both select only those environmental stimuli that are relevant to the pursuit of a certain goal, allowing for deep and accurate processing of the same, and the capacity to contextually suppress information that is irrelevant to the performance of a given task (Stevens & Bavelier, 2012).

Domain-specific cognitive precursors

Domain-specific cognitive precursors of mathematics learning include a wide variety of basic skills pertaining to the strictly numerical domain and specifically associated with mathematics competence. Symbolic skills are specific basic skills crucial for the later development of arithmetic skills and general mathematics competence. A large body of studies suggests that young children's general mathematics achievement may be more strongly related to performance on symbolic tasks, involving Arabic numerals, than to performance on non-symbolic measures (for meta-analyses see Chen & Li, 2014; Fazio et al., 2014).

Among the key domain-specific symbolic precursors of mathematics learning is verbal counting skill, which, as it involves the child's understanding of the relationship between the counted elements and the numerical verbal label, constitutes a cornerstone for the development of early mathematics competence (Clements & Sarama, 2007), also acting as a predictor of mathematics learning at primary school (Nguyen et al., 2016; Passolunghi et al., 2007). In this regard, previous research indicated that counting abilities pose significant predictors for the basic numerical and magnitude competencies (e.g., magnitude comparison) in preschoolers (Pixner et al., 2017). In line with this, Manfra et al. (2014) found that children who were able to count and recite to 20 during the first half of preschool reached the highest mathematical performance in first grade. Similarly, evidence shows that difficulties in counting are associated with later math difficulties during formal schooling (Ouyang et al., 2023).

In the context of the development of counting skills, recent research has shown that the acquisition of the cardinality principle, i.e., the understanding that the last word-number in a counting sequence represents the quantity of the elements of the counted set, is strongly associated with students' subsequent knowledge of the number system and their "readiness" for mathematics learning in formal schooling (Geary et al., 2018; Geary et al., 2019; Krajcsi & Reynvoet, 2024). Specifically, research has shown that the development of numerosity-based representations seems to be associated with cardinality knowledge (Rousselle et al., 2004). Studies suggest that children who achieve an early understanding of cardinality knowledge have a better comprehension of the relations among numerals upon primary school entry, thus establishing a developmental bridge between cardinality knowledge and school-entry number knowledge (Geary & vanMarle, 2018). Notably, cardinality knowledge is critical for the mathematical skill development of preschool children, as mastering the cardinality principle signifies the onset of children's semantic representation of symbolic number knowledge (Göbel et al., 2014). Moore et al. (2016) revealed indeed that preschoolers' cardinality knowledge and competence in implicit arithmetic predict later fluency of magnitude processing. This underscores the importance of focusing on the foundational elements of children's emerging competence in symbolic mathematics, rather than on non-symbolic numerical skills. Consistent with this point, van 't Noordende et al., 2021suggested that non-symbolic quantity comparison does not contribute much to the development of early numerical cognition in preschoolers. Moreover, in a longitudinal study, Xenidou-Dervou et al. (2017) showed that, while non-symbolic comparison skill was moderately predictive only in preschool, symbolic comparison ability was a robust and consistent predictor of future mathematics across all three years of preschool.

The ability to recognize digits, another domain-specific precursor involving both symbolic number knowledge and understanding of the meaning of the number word, has also been found at preschool age to be predictive of later mathematics competence (for a review, see Merkley & Ansari, 2016). For instance, knowledge of Arabic numerals in six-year-olds was found to predict the longitudinal development of their arithmetic skills (Göbel et al., 2014), representing a key indicator of mathematical learning from preschool onwards (Cahoon et al., 2021). Furthermore, evidence suggests that difficulties with tasks involving Arabic digits are common among children who experience mathematical learning difficulties during formal schooling (Bartelet et al., 2014; Rousselle et al., 2004).

Early assessment and promotion of general precursors are useful in preventing the risk of developing mathematics difficulties, especially in light of evidence showing that inter-individual differences in precursors tend to exacerbate level differences in mathematics competence over time (e.g., Morgan et al., 2011). In light of the aforementioned literature, we believe that assessing the domain-specific precursors of counting, digit recognition, and cardinality is appropriate both for the age of the sample considered in the present study (i.e., three and four years old) and for the relevance these constructs have in predicting future learning and profiles of mathematical learning difficulties (Bartelet et al., 2014; Geary & vanMarle, 2018; Ouyang et al., 2023; Rousselle & Noël, 2007). However, it is worth noting that relatively few training studies have specifically targeted first-year preschoolers with numerical difficulties (e.g., Van Herwegen et al., 2017). This highlights a gap in the literature and underscores the importance of our focus in this critical developmental stage.

Training interventions to promote early development of mathematics learning

Despite the paucity of research in this area, the available literature nevertheless shows how properly designed interventions can enhance early numeracy skills. For instance, domain-specific training has been found to be effective in promoting skills such as counting (Kyttälä et al., 2015; Passolunghi & Costa, 2016; Whyte & Bull, 2008), cardinality (Mix et al., 2012; Paliwal & Baroody, 2018), addiction, and subtraction with concrete as well as imaginary objects (e.g., Young-Loveridge, 2004). These training interventions were presented to typically developing children as interactive face-to-face game activities especially for three-to-four (Mix et al., 2012; Paliwal & Baroody, 2018; Whyte & Bull, 2008), or five-to-six year old children (Kyttälä et al., 2015; Passolunghi & Costa, 2016; Young-Loveridge, 2004) in small groups, or individually for younger children (see Mix et al., 2012; Paliwal & Baroody, 2018).

Other studies have also shown that early numeracy can be successfully enhanced even in "at-risk" (low achievers or disadvantaged socioeconomic [SES] context) children. Trainings have been implemented in three-to-four (Van Herwegen et al., 2017) and four-to-five (Siegler & Ramani, 2009; Tobia et al., 2021) year old children and before the formal entry into primary school (Aunio et al., 2021; Clarke et al., 2016; Dyson et al., 2013; Räsänen et al., 2009; Salminen et al., 2015). In particular, in a study by Aunio et al. (2021), the authors found that the at-risk intervention group improved more in relational numerical skills compared to both the at-risk and the average numerical skills control groups. Similarly, in a study by Clarke et al. (2016), the authors showed that students made statistically significant larger gains compared to their not-at-risk peers, despite no differences in gains emerging at the follow-up, six-months later. However, other studies have shown that children at risk may show within-group improvement but no difference with respect to the control groups (Aunio et al., 2021; Salminen et al., 2015). In this sense, it has been proposed in the literature that children at risk of developing numerical difficulties might be more resistant to improvements (Aunio et al., 2021), making it necessary to conduct further studies at an early age when interventions might be more effective.

Furthermore, the domain-specific trainings examined in the literature to date have either been conducted through face-to-face (individual or group) interventions, where researchers engage groups of children in educational activities, or implemented through a computer-based modality. Given the complex cognitive process involved (Aladé et al., 2016), this latter type of intervention has been designed for individual activities with older children: from four-to-five (Schacter & Jo, 2016; Schroeder & Kirkorian, 2016) five-to-six (Aunio et al., 2021; Sella et al., 2016) or six-to-seven year old children (Räsänen et al., 2009; Salminen et al., 2015).

Despite a widespread and now pervasive trend in using active computer-based educational activity (Rideout & Robb, 2017), much less is known concerning the role of passive video exposure (i.e., without any other form of reinforcement or educational activity on numeracy) in numerical promotion for preschoolers. Some studies indicate that learning through videos can be challenging for children under the age of three, limiting the transferability of learning across various assessment contexts (Anderson et al., 2001; DeLoache et al., 2010; Rice et al., 1990; Troseth, 2010). However, the effects of exposure to educational videos with numerical content on preschool children's numerical skill development are still unclear today, especially when considering children at risk of developing numerical difficulties and are therefore particularly important to investigate further.

Although scarce, the literature on the topic has focused on the role of educational TV programs (Ball & Bogatz, 1970; Bogatz & Ball, 1971) showing positive effects on language, mathematics (Mares & Pan, 2013) and daily life skills (Anderson et al., 2001; Fisch et al., 1999; Linebarger & Walker, 2005; Rice et al., 1990). Few studies, however, have evaluated the effectiveness of passive exposure to videos in promoting numerical skills. For example, some studies have shown a positive effect of numerical videos on sequencing skills (Lauricella et al., 2011), measurement abilities (Aladé et al., 2016), and quantity discrimination (Schroeder & Kirkorian, 2016). In other words, although preschool-aged children watch videos daily in various contexts of their everyday lives (Marsh et al., 2019; Rideout & Robb, 2017), the educational effectiveness of passive exposure to these in the field of numerical learning is still uncertain.

The present study: purpose and hypothesis

Most of the studies mentioned above involved either the implementation of face-to-face group training interventions or the individual use of interactive apps to improve children's numerical skills. Furthermore, as already noted, only a few studies have examined the effects of passive exposure to videos with numerical content on domain-specific cognitive skills such as counting and cardinality (Cuder et al., 2022), and no research to date has investigated the effectiveness of such passive exposure on the numerical skills of children at risk of developing numerical difficulties. In response to these gaps found in the literature and considering that video content enjoyment is now increasing among preschool children (Marsh et al., 2019; Rideout & Robb, 2017), the general purpose of the present study is to evaluate the effectiveness of a video-based training intervention involving passive exposure to videos with numerical content promoting numerical skills (i.e., counting, digits recognition, cardinality), in a sample of first-year preschool children. Given the role that domain-general precursors play in supporting the development of domain-specific skills (e.g., Ashkenazi & Shapira, 2017; Dupont-Boime & Thevenot, 2018; Gray & Reeve, 2016; Lane & Pearson, 1982; Posner & Petersen, 1990), this study evaluated verbal intelligence, visuospatial WM, and selective attention as covariate to determine the effectiveness of the intervention, while accounting for potential confounders.

The first aim of the present study was to compare the effectiveness of the training by considering two intervention groups: children with average numerical skills and children at risk of developing numerical difficulties. As shown in other studies, children with average numerical abilities demonstrate improvements in counting (Cuder et al., 2022; Passolunghi & Costa, 2016; Young-Loveridge, 2004), digit recognition (Krajewski & Schneider, 2009; Lira et al., 2017), and the development of cardinality understanding (Geary et al., 2019; Geary & vanMarle, 2016; Paliwal & Baroody, 2018) following numerical interventions. Furthermore, evidence shows that children at risk of developing numerical difficulties are characterized by an increased risk of persistent numerical and math difficulties in subsequent school years (Murphy et al., 2007; Zhang et al., 2020). Meta-analytic evidence suggests that interventions targeting at-risk children can be highly effective in improving numeracy skills, particularly in preschool children (Nelson & McMaster, 2019). In relation to the first aim of the study and the literature described above, we hypothesized that the intervention groups (i.e., children with average numerical skills and at-risk children) would exhibit statistically significantly greater gains in numerical skills (counting, cardinality, and digit recognition) compared to the control group with average numerical skills.

The second aim was to assess the persistence of the intervention's effects over time. We conducted a follow-up post-test five months after the intervention concluded. Few studies in the literature have considered a delayed post-test to evaluate the long-term effectiveness of interventions. Evidence suggests that numerical interventions are effective, producing improvements with medium to large effect sizes (Nelson & McMaster, 2019), which can persist over time (Cuder et al., 2022). In relation to the second aim of the study and in light of the literature discussed, we hypothesized that statistically significant gains in numerical skills (counting, cardinality, and digit recognition) would be observed in the intervention groups (i.e., children with average numerical skills and at-risk children) compared to the control group with average numerical skills at the 5-month post-test.

Method

Participants

Preschools were randomly selected from a database of public schools in the northeastern part of Italy. Once the preschools were identified, the principals were contacted and informed about the study's procedures. After obtaining approval from the principals, informational meetings were held with the teachers and parents to further explain the study activities and obtain informed consent for the children's participation. As a result of this process, six preschools were recruited to participate in the study. A total of 146 preschool children attending the first year of preschool were recruited. Five children were excluded at the beginning of the study due to the presence of a diagnosis or assessment of ongoing neurodevelopmental disorders, and three were excluded for being outliers in verbal intelligence and numerical tasks, with extremely low performances. In addition, three children were further excluded because they were absent from more than two sessions of the training intervention during the study. The final sample thus comprised 135 participants ($M_{months} = 43.64$, $SD_{months} = 4.14$, Females = 47.4 %).

Theoretically, children at risk of developing numerical difficulties could be identified as early as preschool age (Van Herwegen et al., 2018), and are characterized by an increased risk of persistent numerical and mathematics difficulties in subsequent school years (Murphy et al., 2007; Zhang et al., 2020). Children are usually classified as at risk of developing numerical difficulties based on cutoff values that are generally derived from specific threshold percentiles observed in the studies' samples (Nelson & McMaster, 2019), which in the literature can vary from the 25th to the 50th percentile (; Aunio et al., 2021; Nelson & McMaster, 2019; Toll & Van Luit, 2012). In a recent study by Aunio et al. (2021), the authors used the 30th percentile to identify children at risk of developing numerical difficulties, showing how it is adequate to identify children who display weaknesses or gaps in their numerical skills. In this context, in our study, we decided to use an instrument standardized in the Italian population (BAS3; Elliott et al., 2021; for a detailed description of the task, please refer to the 'Measures' section) to assess children's numerical skills. Subsequently, we planned to identify the 30th percentile in our sample, comparing the raw score associated with the sample 30th percentile with the reference norms of the Italian population. Following this procedure, participants with a score below the 30th percentile (corresponding to $BAS3_{raw\ score} = 9$) were considered to be at risk of developing numerical difficulties and, therefore, included in the intervention group defined as "at risk" ($n = 41$, $M_{months} = 41.17$, $SD_{months} = 3.28$, Females = 51.2 %). In contrast, children who scored above the 30th percentile, i.e., with average numerical skills, were randomly assigned either to the second intervention group ($n = 48$, $M_{months} = 43.69$, $SD_{months} = 3.17$, Females = 50.0 %) or to the active control group ($n = 46$, $M_{months} = 45.78$, $SD_{months} = 4.56$, Females = 41.3 %). To increase the transparency and validity of the sample grouping procedure, we compared the raw score of the BAS3 subscale with the Italian normative scores. Specifically, the raw score obtained with the BAS3 (i.e., BAS3 raw score = 9) corresponded to national normative scores that could range between the 25th and 30th percentile, depending on the child's age. This range of percentiles was comparable to that observed in the intervention literature, where screenings for children at risk of developing numerical difficulties typically consider performances below the 25th or 30th percentile (Aunio et al., 2021; Nelson & McMaster, 2019).

At 5-months post-test, some children were no longer contactable, so they were excluded from the analysis. We excluded 14 children from the "at-risk" intervention group ($n = 27$), 12 from the average intervention group ($n = 36$), and 6 from the average numerical skills control group ($n = 40$). No significant difference was found between the three groups in terms of the age of the participants ($F(2,132) = 0.33$, $p = .72$).

The children in the sample considered were mostly of Caucasian origin and Italian native speakers and, according to preschool records, from families of average socio-economic status. The study received approval by the ethical committee of the University of Trieste and was conducted in compliance with the Declaration of Helsinki, the ethical guidelines of the Italian Association of Psychology, and the ethical code of the Italian Register of Professional Psychologists. Written informed parental consent was obtained before assessing the students.

Procedures

This study is part of a larger project on early numerical learning in children called "I Count: Group Play Activities to Promote Math Abilities and Reduce Early Learning Discrepancy". The evaluations of children's domain-general and numerical skills in the different study phases and the intervention were conducted by a team of professional psychologists specifically trained for the administration of the tests used in the study and who had previous experience in conducting this type of activity with preschool children. This professional team was blind to the objectives and hypotheses of the study. Both the assessments and the training were conducted during preschool hours in the morning. The study participants were involved in the four phases described below.

- Pre-test. In the pre-test phase, in two sessions lasting 20 min each, the children's domain-general cognitive abilities and numerical skills were assessed. More specifically, verbal intelligence, selective attention, and low-control verbal and visuo-spatial WM skills were examined. In addition, numerical skills (i.e., counting, cardinality, and digit recognition) were assessed. All evaluations were conducted individually in a quiet room in the preschool free from distracting stimuli and with adequately bright lighting.
- Training intervention. In the intervention phase, the study participants, in small groups of three or four children, were exposed to some videos with numerical content (in the case of the two intervention groups "at risk" and "average" numerical skills) or to control videos (in the case of the active control group). Children were taken to a quiet room in the preschool and sat in front of a 17-in. screen on which the videos were played. While the video was playing, the researcher stood behind the children in silence, checking that the videos were playing correctly. The training comprised two sessions per week for a total of six weeks (i.e., twelve sessions). In each session, the children were exposed to two different videos.
- Post-test. In the post-test numerical skills were assessed again.
- 5-months post-test. Numerical skills were reassessed five months after the post-test.

Characteristics of the training intervention

Videos with numerical content were created using animation and video editing software. In order to obtain similar videos for the two intervention groups ("at risk" and "average" numerical abilities), an animation was developed where specific objects (ranging from 1 to 10) sequentially appeared in the center of the screen. The control group watched videos similar to those shown to the intervention groups, but they focused on fruits and objects' colors rather than counting sequences and digits recognition (see Table 1 for a description of the videos produced). In the counting videos, a character (specifically a cat) was positioned at the bottom left of the screen, and it counted the objects that appeared. In the digit-recognition videos, the character would comment on the sets of objects that appeared and pronounce aloud the digit corresponding to the number of objects in each set as it appeared in

Table 1
Topics, duration and content description of the videos shown to participants during the training intervention.

	Topic	Duration in minutes	Content description
Video for intervention groups			
1	Counting	5	The character engaged in a counting activity from 1 to 9. Example: the cat had to count the white dots on the cap of some mushrooms.
2	Counting	5	The character engaged in a counting activity from 1 to 10. Example: the cat had to count the fruit placed inside a crate.
3	Counting	5	The character engaged in a counting activity from 1 to 10. Example: the cat had to count the candies inside a plastic bottle.
4	Digit recognition	5	The character engaged in a digit recognition activity of numbers from 1 to 9. Example: the cat commented on the white dots on the cap of some mushrooms and pronounced aloud the digit corresponding to the number of dots on each mushroom as it appeared on the screen.
5	Digit recognition	5	The character engaged in a digit recognition activity of numbers from 1 to 10. Example: the cat commented on the fruits placed inside some crates and pronounced aloud the digit corresponding to the number of fruits in each crate as it appeared on the screen.
6	Digit recognition	5	The character engaged in a digit recognition activity of numbers from 1 to 10. Example: The cat commented on the sweets contained inside some plastic bottles and pronounced aloud the digit corresponding to the number of sweets in each bottle as the latter appeared on the screen.
Video for the control group			
1	Colors	5	The character engaged in an activity of naming the colour of flower petals (red, blue, green, yellow).
2	Colors	5	The character engaged in an activity of naming the colour of cars (red, orange, green, yellow).
3	Colors	5	The character engaged in an activity of naming the colour of candies (red, orange, purple, yellow).
4	Fruit colors	5	The character engaged in an activity of naming the colour of summer fruits (e.g., peach, watermelon, melon, kiwi).
5	Fruit colors	5	The character engaged in an activity of naming the colour of spring fruits (e.g., cherries, strawberries, oranges).
6	Fruit colors	5	The character engaged in an activity of naming the colour of autumn fruits (e.g., persimmon, chestnut, pear, pomegranate).

the bottom right part of the screen. Once the animation was completed, the videos were dubbed. In total, six videos were produced for the intervention groups (three related to counting and three related to digit recognition) and six videos for the control group, each lasting five minutes.

Measurements

Early numeracy

As mentioned in the "Participants" section of this paper, the Early Number Concepts subtest of the British Ability Scales test (BAS3, standardized Italian version by Elliott et al., 2021) was administered to assess early numeracy skills in order to identify children at risk of developing difficulties in this area. The test includes 30 items that assess various aspects of early numerical competence, such as number concepts, understanding of quantities, and basic arithmetic operations. Specific materials are used, which include ten plastic tokens and cards depicting different images that the child must use as an aid and reference to answer the questions posed by the examiner. Each item is given a score of one in the case of a correct answer and zero in the case of an incorrect answer, with the exception of the third item, which is assessed with a maximum score of six in the case of a correct answer (expected score range: 0–35). The test is self-terminating and stops after five consecutive mistakes. Test-retest reliability of the instrument was satisfactory ($r = 0.76$).

Domain-general cognitive skills

Verbal intelligence. To assess children's verbal intelligence, the "Receptive Vocabulary" subtest of the Wechsler Preschool and Primary Scale of Intelligence - Fourth Edition (WPPSI-IV; Wechsler, 2012) was administered. This subtest is sometimes used as a proxy for verbal intelligence (Critten et al., 2018). On each trial of the task, participants are presented with four printed pictures and asked to indicate the picture that best matches the meaning of the word spoken by the examiner. One point is awarded for each correctly identified picture (expected score range: 0–38). Again, the test is self-terminating and stops after five consecutive errors. Test-retest reliability of the instrument was good ($r = 0.94$).

Selective attention. To assess children's selective attention, a task adapted from an attention subtest of the Neuropsychological Assessment Battery for Adolescents (BVN 12–18; Gugliotta et al., 2009) and Children (BVN 5–11; Bisiacchi et al., 2005) was used. This prototypical task was specifically modified to suit the developmental level of the sample considered by adapting the visual stimuli and timing. The test involves participants watching a video where, at one-second intervals, they are presented with various visual stimuli in a changing sequence. Children are asked to clap their hands on the table whenever the target stimulus, i.e., the image of a sun, appears on the screen. One point is awarded for each correct response, i.e., for each correctly identified target stimulus (expected score range: 0–20). Test-retest reliability of the instrument was good ($r = 0.92$).

Verbal WM. To assess low-control verbal WM skills, the word span task was administered (Lanfranchi et al., 2004). Participants are presented with lists of commonly used disyllabic words and asked to repeat them in the same order of presentation. The test comprises four levels of difficulty, depending on the number of words to be memorized included in each list, and comprises a total of eight trials, two for each level. The score reflects the level (i.e., span) achieved by the child: one point is awarded for each level successfully passed (expected score range: 0–4). The test is self-terminating: it stops when the child recalls incorrectly or cannot remember the two sets of words of the same level of difficulty. The test-retest reliability of the instrument was good ($r = 0.89$).

Visuo-spatial WM. To measure low-control visuo-spatial WM skills, children are shown paths of increasing length taken by a toy frog on a matrix and are asked to recall, in the same order of presentation, the movements made by the frog from one square to another on the matrix (Lanfranchi et al., 2004; Lanfranchi et al., 2009). The test includes four levels of difficulty, depending on the number of movements of the frog in the matrix, for a total of eight trials. The score reflects the level (i.e., span) reached by the child: one point is awarded for each successfully passed level (expected score range: 0–4). The test is self-terminating: it is interrupted when the child recalls incorrectly or fails to remember the two paths of the same level of difficulty. Test-retest reliability of the instrument is good ($r = 0.80$).

Domain-specific cognitive skills

Counting. To measure counting ability, a task adapted from the subtest entitled 'Forward Enumeration' of the Battery for the Assessment of Numerical Intelligence (BIN 4–6; Molin et al., 2007) was administered. In this test, children are asked to count forward from 1 to 20 by reciting the number sequence aloud. The total score coincides with the highest correctly counted number (expected score range: 0–20). Test-retest reliability of the instrument is good ($r = 0.83$).

Digit recognition. To assess digit recognition ability, a task adapted from the BIN subtest 'Name-Number Correspondence' (Molin et al., 2007) was used in which children are shown the digits 1–9 printed on white cards in random order and are asked to name aloud the digit presented each time. The total score corresponds to the number of digits correctly recognized by the child (expected score range: 0–9). Test-retest reliability of the instrument is good ($r = 0.85$).

Cardinality. In order to measure the cardinality knowledge, our task was adapted from Le Corre and Carey's (2007) "What's on This Card" test. This task is commonly used in the literature with various adaptations, and it is often known also as the "How many task" (e.g. Litkowski et al., 2020; Paliwal & Baroody, 2018). Children were presented with nine cards, in a random order, depicting between one and nine colored objects. For each card, participants are first asked to count the objects represented on the cards and, secondly, to say how many objects are depicted. In comparison to the original task (see Le Corre & Carey, 2007), our version varied the number of objects on each card (ranging from 1 to 9) but maintained the same task requirements: count the set and then report the total number of objects depicted. A point is awarded if the children not only count the objects correctly but also answer the second question correctly without counting them again (expected scoring range: 0–9). Test-retest reliability of the instrument is good ($r = 0.84$).

Results

The descriptive statistics of the different measures used are shown in Table 2. Bivariate correlations between the different variables are reported in Table 3.

Preliminary analysis: pre-test evaluation

To test whether the three groups of children differed from each other in the pre-test phase, a multivariate analysis of variance (MANOVA) was conducted with the group (at-risk intervention group, average numerical skills intervention group, and average numerical skills control group) as a fixed factor, and the pre-test scores on the tests related to domain-general cognitive abilities (verbal intelligence, selective attention, low-control verbal WM and low-control visuo-spatial WM) and domain-specific abilities (counting, cardinality, digit recognition) as dependent variables. In order to compare the differences between the control group with average numerical skills and both intervention groups (at-risk and with average numerical skills), planned contrasts were used. In addition, Cohen (2013) were used to assess the differences between the groups' pre-test scores and to classify the effect size: small ($\eta_p^2 = 0.01$), medium ($\eta_p^2 = 0.06$), large ($\eta_p^2 = 0.14$) effects.

The results of the MANOVA showed a significant group effect (Wilks' Lambda = 0.53, $F(2,132) = 6.64$, $p < .001$) indicating the presence of statistically significant differences between the three groups at the pre-test stage (see Table 4 for univariate and planned contrasts results). The results of the univariate tests revealed statistically significant differences in verbal intelligence $F(2, 132) = 35.32$, $p < .001$, $\eta_p^2 = 0.35$, in selective attention $F(2, 132) = 14.93$, $p < .001$, $\eta_p^2 = 0.18$, in low-control visuo-spatial WM $F(2, 132) = 8.09$, $p < .001$, $\eta_p^2 = 0.11$, in counting $F(2, 132) = 11.63$, $p < .001$, $\eta_p^2 = 0.15$, in cardinality $F(2, 132) = 15.42$, $p < .001$, $\eta_p^2 = 0.19$, and in digit recognition $F(2, 132) = 5.72$, $p = .004$, $\eta_p^2 = 0.08$. No significant differences were found between groups in low-control verbal WM $F(2, 132) = 0.12$, $p = .883$, $\eta_p^2 < 0.01$.

Planned contrasts showed that the average numerical skills control group scored significantly higher than the at-risk intervention group on verbal intelligence $F(1,132) = 70.01$, $p < .001$ $\eta_p^2 = 0.35$, selective attention $F(1, 132) = 28.88$, $p < .001$, $\eta_p^2 = 0.18$, low-control visuo-spatial WM $F(1, 132) = 16.17$, $p < .001$, $\eta_p^2 = 0.11$, counting $F(1, 132) = 23.09$, $p < .001$, $\eta_p^2 = 0.15$, cardinality $F(1, 132) = 27.36$, $p < .001$, $\eta_p^2 = 0.17$, and digit recognition $F(1, 132) = 10.68$, $p = .001$, $\eta_p^2 = 0.07$. No significant differences were found between the average numerical skills control group and the average numerical skills intervention group in any of the measures considered, i.e., verbal intelligence $F(1, 132) = 0.63$, $p = .429$ $\eta_p^2 < 0.01$, selective attention $F(1, 132) = 0.99$, $p = .323$, $\eta_p^2 = 0.01$, low-control visuo-spatial WM $F(1, 132) < 0.001$, $p = .996$, $\eta_p^2 < 0.01$, counting $F(1, 132) = 0.173$, $p = .678$, $\eta_p^2 < 0.01$, cardinality $F(1, 132) = 3.48$, $p = .064$, $\eta_p^2 = 0.03$, digit recognition $F(1, 132) = 0.76$, $p = .383$, $\eta_p^2 = 0.01$.

Post-test evaluation

In the post-test evaluation phase, gains (the difference between the children's post-test and pre-test scores) were calculated for the domain-specific cognitive skills. The consideration of gains represents an

Table 2
Descriptive statistics and reliabilities of measures for the three groups of children in the three phases of the study (pre-test, post-test and 5-months post-test).

		At-Risk intervention group			Average numerical skills intervention group			Average numerical skills control group		
		Pre-test n = 41	Post-test n = 41	5-months post-test n = 27	Pre-test n = 48	Post-test n = 48	5-months post-test n = 36	Pre-test n = 46	Post-test n = 46	5-months post-test n = 40
Verbal intelligence	M (SD)	15.15 (6.41)	–	–	23.25 (4.40)	–	–	24.26 (5.65)	–	–
Selective attention	M (SD)	12.58 (4.73)	–	–	15.87 (3.49)	–	–	16.67 (2.61)	–	–
Verbal WM	M (SD)	2.95 (0.58)	–	–	3.02 (0.84)	–	–	3.00 (0.51)	–	–
Visuospatial WM	M (SD)	1.88 (1.42)	–	–	2.73 (0.87)	–	–	2.74 (1.10)	–	–
Counting	M (SD)	5.19 (3.98)	10.27 (3.11)	10.55 (3.81)	8.98 (4.75)	13.37 (4.73)	14.42 (4.79)	9.41 (4.51)	9.69 (5.15)	11.47 (5.49)
Digit recognition	M (SD)	1.71 (2.18)	2.83 (2.81)	3.78 (3.46)	3.23 (3.26)	4.19 (3.38)	5.55 (3.27)	3.78 (3.16)	4.35 (3.38)	4.45 (3.49)
Cardinality	M (SD)	1.05 (1.72)	2.63 (2.75)	4.52 (3.08)	3.10 (2.95)	5.52 (3.05)	7.42 (2.03)	4.15 (2.94)	5.72 (2.89)	5.97 (2.92)

Note: M = Mean, SD = standard deviation, WM = Working Memory.

Table 3
Bivariate correlations between the measures at the pretest evaluation.

	1.	2.	3.	4.	5.	6.	7.
1. Early numeracy	–						
2. Verbal intelligence	0.61**	–					
3. Selective attention	0.46**	0.42**	–				
4. Verbal WM	0.08	0.16	0.10	–			
5. Visuospatial WM	0.36**	0.39**	0.33**	0.22**	–		
6. Counting	0.54**	0.31**	0.33**	0.10	0.16	–	
7. Digit recognition	0.45**	0.17*	0.20*	−0.06	0.14	0.41**	–
8. Cardinality	0.49**	0.37**	0.24**	0.06	0.28**	0.32**	0.46**

Note: WM = Working Memory.
** $p < .01$.
* $p < .05$.

Table 4
Univariate planned contrast results between groups: at-risk intervention group compared to the average control group; and average intervention group compared to the average control group.

	Univariate test results				Planned contrasts							
					At-risk intervention group vs. average control group				Average intervention group vs. average control group			
	F	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2	*F*	*df*	*p*	η_p^2
Pre-test												
Verbal intelligence	35.39	2, 132	<0.001***	0.35	70.01	1, 132	<0.001***	0.35	0.63	1, 132	0.429	<0.01
Selective attention	14.93	2, 132	<0.001***	0.18	28.88	1, 132	<0.001***	0.18	0.99	1, 132	0.323	0.01
Verbal WM	0.12	2, 132	0.883	<0.01	0.22	1, 132	0.637	<0.01	0.02	1, 132	0.876	<0.01
Visuospatial WM	8.09	2, 132	<0.001***	0.11	16.17	1, 132	<0.001***	0.11	<0.001	1, 132	0.996	<0.01
Counting	11.63	2, 132	<0.001***	0.15	23.09	1, 132	<0.001***	0.15	0.17	1, 132	0.678	<0.01
Digit recognition	5.724	2, 132	0.004**	0.08	10.68	1, 132	0.001**	0.07	0.76	1, 132	0.393	0.01
Cardinality	15.42	2, 132	<0.001***	0.19	27.36	1, 132	<0.001***	0.17	3.48	1, 132	0.064	0.03
Post-test												
Counting	14.52	2, 129	<0.001***	0.18	6.09	1, 129	0.015*	0.05	22.95	1, 129	<0.001***	0.15
Digit recognition	0.93	2, 129	0.396	0.01	0.95	1, 129	0.331	<0.01	0.91	1, 129	0.341	0.01
Cardinality	1.41	2, 129	0.249	0.02	0.60	1, 129	0.439	<0.01	2.21	1, 129	0.140	0.02
5-month Post-test												
Counting	7.67	2, 97	0.001**	0.14	6.04	1,97	0.016*	0.06	9.29	1, 97	0.003**	0.09
Digit recognition	4.05	2, 97	0.020*	0.08	0.57	1, 97	0.451	<0.01	13.33	1, 97	0.001**	0.12
Cardinality	6.73	2, 97	0.002**	0.12	0.14	1, 97	0.708	<0.01	7.53	1, 97	0.007**	0.07

Note: F = F-test, df = degrees of freedom, p = p-value, η_p^2 = Partial eta-square effect size, WM = Working Memory.
*** $p < .001$.
** $p < .01$.
* $p < .05$.

analytical strategy commonly reported in the literature with reference to training interventions (e.g., Brehmer et al., 2012; Pellizzoni et al., 2019). A MANOVA was conducted using group as a fixed factor and gains in numerical skills as dependent variables. Since the at-risk intervention group and the average numerical skills control group differed in the domain-general cognitive abilities measured in the pre-test (i.e., verbal intelligence, selective attention and low control visuo-spatial WM), these variables were considered as covariates.

The MANOVA results showed a significant group main effect (Wilks' Lambda = 0.79, $F(2,129) = 5.29$, $p < .001$) indicating the presence of statistically significant differences between the three groups in the post-test (see Table 4 for univariate and planned contrasts results). The univariate test results revealed statistically significant differences between the groups in counting $F(2, 129) = 14.52$, $p <. 001$, $\eta_p^2 = 0.18$ but not in cardinality $F(2, 129) = 1.41$, $p = .249$, $\eta_p^2 = 0.02$, and digit recognition $F(2, 129) = 0.93$, $p = .396$, $\eta_p^2 = 0.01$.

Planned contrasts showed that the control group with average numerical skills produced a smaller gain in counting than the two intervention groups, i.e., average numerical skills intervention group $F(1, 129) = 22.95$, $p < .001$, $\eta_p^2 = 0.15$ and at-risk intervention group $F(1, 129) = 6.09$, $p = .015$, $\eta_p^2 = 0.05$. Contrasts also revealed that the gains of the average numerical skills control group did not differ significantly from those of the average numerical skills intervention group in cardinality $F(1, 129) = 2.21$, $p = .140$, $\eta_p^2 = 0.02$, and digit recognition $F(1, 129) = 0.91$, $p = .341$, $\eta_p^2 = 0.01$. Similarly, comparisons showed no statistically significant differences in gains between the average numerical skills control group and the at-risk intervention group in cardinality $F(1, 129) = 0.60$, $p = .44$, $\eta_p^2 < 0.01$, and digit recognition $F(1, 129) = 0.95$, $p = .33$, $\eta_p^2 < 0.01$.

5-month post-test evaluation

In the 5-month post-test phase, the gains (i.e., the difference between the children's 5-month post-test and pre-test scores) in the numerical skills (i.e., counting, cardinality and digit recognition) were calculated. We conducted a MANOVA with the group as a fixed factor and the gains in the scores of the numerical skills as dependent variables. In addition, domain-general cognitive abilities assessed in the pre-test phase, i.e., verbal intelligence, selective attention and low-control visuo-spatial WM, were considered as covariates.

The results showed a significant group main effect (Wilks' Lambda = 0.76, $F(2, 97) = 4.60$, $p < .001$) indicating the presence of statistically significant differences between the groups (see Table 4 for univariate and planned contrasts results). Indeed, univariate analyses revealed statistically significant differences between the groups in counting $F(2, 97) = 7.66$, $p = .001$, $\eta_p^2 = 0.14$, cardinality $F(2, 97) = 6.73$, $p = .002$, $\eta_p^2 = 0.12$, and digit recognition $F(2, 97) = 4.05$, $p = .020$, $\eta_p^2 = 0.08$.

A priori planned contrasts showed that the control group with average numerical skills produced a smaller gain in counting than the two intervention groups, i.e., the average numerical skills intervention group $F(1, 97) = 9.29$, $p = .003$, $\eta_p^2 = 0.09$ and the at-risk group $F(1, 97) = 6.04$, $p = .016$, $\eta_p^2 = 0.06$. Contrasts also revealed that the average numerical skills control group produced smaller gains in cardinality $F(1, 97) = 13.33$, $p < .001$, $\eta_p^2 = 0.12$ and digit recognition $F(1, 97) = 7.53$, $p = .007$, $\eta_p^2 = 0.07$ than the average numerical skills intervention group. There were no statistically significant differences in gains between the average numerical skills control group and the at-risk intervention group with regard to cardinality $F(1, 97) = 0.14$, $p = .708$, $\eta_p^2 < 0.01$ and digit recognition $F(1, 97) = 0.57$, $p = .451$, $\eta_p^2 < 0.01$.

Discussion

Despite the importance of mathematics learning for academic, professional, and personal development and well-being (Foley et al., 2017; Gerardi et al., 2013; Gross et al., 2009; Peterson et al., 2011), evidence suggests that students worldwide have recently shown a significant decline in their mathematics competence (Betthäuser et al., 2023; OECD, 2023). Our study explores the effects of a video-based intervention on the development of numerical skills in a sample of preschoolers, including those at risk of developing numerical difficulties. Studies show that numerical gaps grow over time (e.g., Morgan et al., 2011), highlighting the need for early interventions to prevent the development of numerical difficulties (e.g., Aunio et al., 2021; Clarke et al., 2016). Notably, few studies have examined whether video-based interventions enhance numerical skills for children at risk of developing numerical difficulties. In this context, the present research provides new theoretical insights and practical implications that support the development of numerical training to address numerical difficulties as early as preschool.

Results at the post-test phase indicate a statistically significant effect of the numerical training on the gains in children's counting ability in both intervention groups (i.e., average numerical skills and at-risk groups) compared to the control group with average numerical abilities. This result confirms the original hypothesis and is in line with previous evidence showing that different types of stimulation, such as board games and computerized activities, that engage the counting process can have a positive effect on the counting ability of preschool children (Schacter & Jo, 2016; Siegler & Ramani, 2009). However, despite our initial hypotheses, no difference in gains was found between both intervention groups and the control group in digit recognition and cardinality knowledge. This result contrasts with the literature, which has shown that exposing children to numerical activities can lead to improvements in digit recognition and cardinality understanding (Geary et al., 2019; Geary & vanMarle, 2016; Krajewski & Schneider, 2009; Lira et al., 2017; Paliwal & Baroody, 2018). It also contrasts with meta-analytic evidence from interventions conducted on children at risk of developing numerical difficulties, which indicates that numerical training can produce medium to large improvements in numerical skills (Nelson & McMaster, 2019). However, it should be noted that the sample of children examined in our research is much younger compared to participants considered in other studies. In this regard, it should be emphasized that cardinality knowledge and digit recognition ability develop gradually throughout the preschool years (Litkowski et al., 2020), leaving open the question of whether video-based interventions might be more effective for older children.

Results at the 5-month post-test showed a statistically significant effect of the numerical training on the gains of children's counting ability in both intervention groups (i.e., average numerical skills and at-risk groups) compared to the control group with average numerical abilities. This finding seems to indicate a lasting, long-term effect of the intervention on counting skills, as previously shown in the literature (Cuder et al., 2022). Notably, this persistent improvement – which also benefited children at risk of developing mathematics difficulties – may have been facilitated by the particular developmental stage of the children in the sample, who, being predisposed to acquire counting skills, may have been able to benefit considerably from the proposed training intervention (Geary, 2004; Raghubar & Barnes, 2017). Exposure to training involving the passive viewing of videos with numerical content could, therefore, prove to be a good way to improve the counting skills of three- and four-year-old preschoolers, even if they present difficulties in the numerical domain. Results also showed that the at-risk of developing numerical difficulties intervention group did not show statistically significant differences in 5-month post-test gains in digit recognition ability and cardinality knowledge compared to the control group with average numerical skills. Instead, the average numerical skills intervention group showed significant differences in gains in digit recognition ability and cardinality knowledge compared to the control group. This result — which does not apply to the at-risk intervention group — could have occurred for several reasons. First, the children in the intervention group with average numerical skills might have developed counting skills that, in turn, could have promoted the development of other numerical abilities. Indeed, counting skills in literature are well-known positive predictors of digit recognition and cardinality knowledge development (Geary et al., 2018; Geary & vanMarle, 2016; Paliwal & Baroody, 2018). Secondly, the intervention might have stimulated the children's interest in numerical activities outside of preschool, further reinforcing their numerical skills. In this context, future studies should more carefully control the effectiveness of interventions, also considering the engagement in similar activities (for example, in the home environment) that children might develop as a result of the interventions themselves.

Considering the role of numerical skills in the development of individuals and society, the results of the present study may have significant educational, social, and economic practical implications. Since watching videos is a widespread and popular activity for preschoolers, it can represent an additional tool that complements more traditional approaches for proposing accessible, acceptable, and effective large-scale interventions (Burroughs, 2017; Marsh et al., 2019; Rideout & Robb, 2017). The tendency and, in some cases, the habit of watching videos could, therefore, be exploited to offer evidence-based interventions involving the use of common technological devices (e.g., tablets, smartphones) with an educational intent to achieve learning objectives. In this sense, videos could be used to implement fun and effective trainings even in deprived contexts where numerical skills are poorly trained (Pellizzoni et al., 2020) and, thus, could prevent children from developing difficulties and negative attitudes towards mathematics during their growth and development process (Caviola et al., 2022; Pellizzoni et al., 2022), promoting learning equity and far-sighted social investments.

Limitations and future directions

The study described in this paper is characterized by some limitations. Firstly, the training intervention implemented does not allow the effects of the counting videos to be distinguished from the effects of the digit recognition videos. The children in the two intervention groups were, in fact, exposed to both types of material during the training. Future studies could, therefore, replicate the results of the present research by examining separately the effects of the two types of videos (counting and digit recognition) on the different numerical skills examined (and potentially also on other factors). Furthermore, our study evaluated the score gains following the intervention by comparing children at risk of developing numerical difficulties with a control group with average numerical skills in order to assess the training's effectiveness in closing the performance gap between the two groups of children, similarly to what has been done in previous studies (Aunio et al., 2021; Clarke et al., 2016). For this reason, future studies should confirm our results by integrating an at-risk control group, ensuring that the observed gains are due to the enrolment in the intervention and not a process due to child numerical maturation. Moreover, as counting and digit recognition skills are significantly interrelated, it is difficult to construct videos aimed at stimulating and promoting only and exclusively one of the two skills without also calling into question the other. A further limitation concerns the fact that, given the age of the children in the sample, the cardinality task may have been too complex for some of them, especially in the pre-test phase. This aspect could have influenced the results of the study by reducing the discriminating power of the instruments or the motivation of the children to perform the proposed tasks. Furthermore, as already mentioned, there was no provision for a survey of numerical activities (formal and informal) carried out by children outside of preschool, for example, in the home environment. In this regard, future studies could also include the measurement – pre- and post-intervention - of home numeracy through the administration of a questionnaire to parents to also control the role of these possible stimuli on the development of numerical skills following the training intervention. Finally, it should be noted that the results of our study were obtained on a sample of first-year preschoolers, and therefore future studies should adapt the intervention materials to the characteristics and skill levels of other developmental stages.

Conclusions

The present study results highlighted the effectiveness of a training intervention based on passive exposure to videos with numerical content on the development of counting skills, in both the short and long term, also considering children at risk of developing numerical difficulties. The intervention described was also effective in promoting cardinality knowledge and the ability to recognize digits in the long term, i.e., five months after receiving the intervention, in the case of children with average numerical skills. Overall, the research results showed that videos with numerical content may be useful for the early promotion of numerical skills, even in the case of children at risk of developing numerical difficulties, thus providing an additional tool to support access to educational opportunities and equity among children living in differently resourced educational settings.

CRediT authorship contribution statement

Sandra Pellizzoni: Conceptualization, Methodology, Supervision, Writing – original draft, Supervision. **Alessandro Cuder:** Formal analysis, Investigation, Methodology, Writing – review & editing. **Chiara De Vita:** Investigation, Methodology, Writing – original draft, Writing – review & editing. **Maria Chiara Passolunghi:** Conceptualization, Methodology, Supervision, Project administration, Writing – review & editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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