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LINGUISTIC QUANTIFIERS AND NUMEROSITY IN AUTISM: BEHAVIORAL EVIDENCE REGARDING DECLARATIVE MEMORY COMPENSATION

QUANTIFICADORES LINGUÍSTICOS E NUMEROSIDADE NO AUTISMO: EVIDÊNCIAS COMPORTAMENTAIS SOBRE A COMPENSAÇÃO DA MEMÓRIA DECLARATIVA

CUANTIFICADORES LINGÜÍSTICOS Y NUMEROSIDAD EN EL AUTISMO: EVIDENCIAS CONDUCTUALES SOBRE LA COMPENSACIÓN DE LA MEMORIA DECLARATIVA

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ABSTRACT: This study examined the extent to which the quantifiers todos (all), alguns (some), muitos (many), and poucos (few) modulated numerosity judgments in autistic and non-autistic children and adolescents and assessed their compatibility with the declarative memory compensation hypothesis. The study is motivated by the scarcity of research integrating linguistic quantification, numerical cognition in autism, and declarative/procedural memory. In a forced-choice task, auditory sentences were paired with nonsymbolic visual sets. Quantifier presence increased accuracy from 51.0% to 78.9% in the non-autistic group and from 50.7% to 65.4% in the autistic group. Only quantifier type accounted for variation in latency. Todos and muitos yielded higher accuracy, whereas poucos and alguns yielded lower accuracy. The gain was about 1.9 times greater in the non-autistic group, providing no support for the strong compensation hypothesis. The findings indicate linguistic modulation of numerosity judgments, without evidence of declarative compensation in the autistic group.

KEYWORDS: Autism Spectrum Disorder. Numerosity. Quantifiers. Declarative memory. Psycholinguistics.

RESUMO: *Este estudo examinou em que medida os quantificadores todos, alguns, muitos e poucos modularam o julgamento de numerosidade em crianças e adolescentes autistas e não autistas e avaliou a compatibilidade dos resultados com a hipótese da compensação da memória declarativa. A investigação se justifica pela escassez de estudos que integrem quantificação linguística, cognição numérica no autismo e memória declarativa/procedimental. Em uma tarefa de escolha forçada, sentenças auditivas foram pareadas a conjuntos visuais não simbólicos. A presença do operador elevou a acurácia do grupo não autista de 51,0% para 78,9% e a do grupo autista de 50,7% para 65,4%. Apenas o tipo de operador explicou a variação na latência. Todos e muitos favoreceram maior acurácia; poucos e alguns, menor. O ganho do grupo não autista foi cerca de 1,9 vez maior, não sustentando a formulação forte da hipótese compensatória. Os resultados indicam modulação linguística da numerosidade, sem evidência de compensação declarativa no grupo autista.*

PALAVRAS-CHAVE: *Transtorno do Espectro Autista. Numerosidade. Quantificadores. Memória declarativa. Psicolinguística.*

RESUMEN: *Este estudio examinó en qué medida los cuantificadores todos, algunos, muchos y pocos modularon el juicio de numerosidad en niños y adolescentes autistas y no autistas, y evaluó su compatibilidad con la hipótesis de compensación declarativa. Se justifica por la escasez de estudios que integren cuantificación lingüística, cognición numérica en el autismo y memoria declarativa/procedimental. En una tarea de elección forzada, oraciones auditivas se emparejaron con conjuntos visuales no simbólicos. La presencia del cuantificador elevó la precisión del grupo no autista del 51,0% al 78,9% y la del grupo autista del 50,7% al 65,4%. Solo el tipo de cuantificador explicó la variación en la latencia. Todos y muchos favorecieron una mayor precisión; pocos y algunos, una menor. La ganancia del grupo no autista fue cerca de 1,9 veces mayor, sin sustentar la hipótesis compensatoria fuerte. Los resultados indican una modulación lingüística de la numerosidad, sin evidencia de compensación declarativa en el grupo autista.*

PALABRAS CLAVE: *Trastorno del Espectro Autista. Numerosidad. Cuantificadores. Memoria declarativa. Psicolingüística.*

Introduction

The relationship between language and numerical cognition involves representational systems of different natures that begin to interact over the course of development. Nonsymbolic abilities make it possible to discriminate and represent quantities before mastery of counting and number words, while linguistic systems provide resources for encoding quantitative relations, establishing symbolic categories, and organizing information about sets, magnitudes, and cardinalities. At this interface, language is not the source of numerosity perception, but it participates in the encoding, stabilization, and use of quantitative representations in tasks requiring comprehension, comparison, and decision-making. Studies on quantifier processing consistently show that quantificational information is interpreted in relation to context and can guide the verification of perceptually available sets.

The comparison between autistic and non-autistic participants places this interface within a context of neurocognitive variation, since investigating how these groups benefit from the same linguistic cue makes it possible to examine whether quantifier and numerosity processing follow different trajectories according to neurocondition. In this study, this comparison was interpretively related to the declarative memory compensation hypothesis, according to which declarative mechanisms may support certain forms of performance when systems more closely associated with proceduralization are less efficient. Because declarative memory and procedural learning were not measured directly, the hypothesis was examined through the compatibility between the observed behavioral pattern and a prediction derived from this proposal.

The empirical gap arises from the articulation of these three domains, discussed in greater detail in the Theoretical Framework below: there are studies on quantifier and numerosity processing, on numerical cognition in autism, and on declarative and procedural systems in ASD and other neurodevelopmental disorders. In Brazilian Portuguese, there are investigations of the interface between language and the development of numerical cognition, as well as declarative memory and morphological processing in autistic participants. However, the effect of specific Brazilian Portuguese quantifiers on nonsymbolic numerosity judgments in a direct comparison between autistic and non-autistic participants remains underinvestigated.

The research question was therefore to determine the extent to which the presence and type of the quantifiers all, some, many, and few affect the accuracy and choice latency of autistic and non-autistic children and adolescents in a numerosity judgment task with nonsymbolic visual sets and, interpretively, the extent to which the distribution of these effects is compatible with the declarative memory compensation hypothesis. The general hypothesis predicted modulation of performance by operator presence and type, with the possibility of effects of different magnitudes according to neurocondition. The study also examined conditions designed to favor precise individuation of small sets and approximate estimation of larger sets, seeking to verify the relative weight of linguistic properties and numerosity range on the two behavioral measures.

The general objective was to examine the extent to which quantificational linguistic cues modulate nonsymbolic numerosity judgments in autistic and non-autistic children and adolescents, considering accuracy and choice latency and assessing the compatibility of the observed behavioral pattern with the declarative memory compensation hypothesis. The study thus places quantification at the center of the psycholinguistic problem: the aim is to determine not only whether verbal information favors a quantitative choice, but also how distinct semantic properties of all, some, many, and few organize the mapping between sentence and visual representation and whether this modulation is distributed differently across neuroconditions.

Theoretical framework

Linguistic quantification and numerosity

This relationship requires a distinction among number, cardinality, numerosity, and quantification. Cardinality corresponds to the number of elements composing a set, whereas numerosity refers to the quantity represented by the cognitive system when a collection is perceived, whether through precise mechanisms for individuating a few elements or through the approximate representation of larger magnitudes (Carey, 2009; Feigenson *et al*., 2004). Numerals participate in a symbolic system that makes it possible to express exact cardinal values; quantifiers, in turn, need not specify a particular cardinality. Expressions such as all, some, many, and few encode relations between sets and properties, making linguistic quantification a phenomenon distinct from counting and number naming (Chierchia, 2003; Castilho, 2015). This distinction delimits the object of this study: it investigates the effect of quantificational linguistic information on nonsymbolic numerosity judgments, rather than numeral processing or the execution of counting procedures.

In formal semantics, quantification can be represented as a relation between sets defined within a domain of interpretation. The noun phrase establishes the restriction over which the quantifier operates, while the predicate determines its scope; sentence interpretation depends on the relation established between these sets (Chierchia, 2003). In All the boys are wearing caps, for example, the set of boys constitutes the relevant domain, and the sentence will be true when that set is entirely included in the set of individuals wearing caps. Quantifier conservativity further restricts evaluation to the relation between the set denoted by the noun and its intersection with the predicate, so that cap-wearing individuals who do not belong to the set of boys do not alter the truth value of the sentence. These properties are directly relevant to sentence-picture matching tasks, in which the participant must visually identify the configuration that satisfies the semantic relation introduced by the quantificational expression. In this study, this relation among restriction, scope, and evaluation domain underlies the construction of the experimental stimuli.

The four quantifiers examined have distinct semantic and interpretive properties. All imposes exhaustivity over the relevant domain: the property expressed by the predicate must be satisfied by every element included in the restriction. Some introduces a plural existential condition; its minimal semantic content does not exclude situations in which the property also applies to the entire set, although communicative contexts may produce the pragmatic enrichment “some, but not all” (Chierchia, 2003; Castilho, 2015; Katsos; Bishop, 2011). Many and few do not lexically fix a single quantity: their application depends on an interpretive threshold related to cardinality, proportion, comparison class, and context (Ramotowska *et al*., 2024). Few also has a negative evaluative orientation and is not simply the quantitative complement of many. Variation among exhaustivity, existence, vagueness, and contextual dependence provides linguistic reasons to expect these operators not to produce the same experimental behavior.

This heterogeneity also affects the verification of quantified sentences: a universal operator establishes a condition that can be rejected by identifying a relevant exception, whereas existential, scalar, and vague quantifiers require other procedures for evaluating the set. Experimental literature shows that verification complexity, monotonicity, polarity, vagueness, and contextual configuration can modify quantifier processing and its relation to perceived numerosity (Deschamps *et al*., 2015; Szymanik; Zajenkowski, 2013; Ramotowska *et al*., 2024). From a psycholinguistic perspective, therefore, comparing all, some, many, and few makes it possible to test not only whether the presence of quantificational information changes the response, but also whether specific properties of that information produce distinct accuracy and latency profiles.

The other dimension of the experiment concerns the nonsymbolic representation of quantity. The numerical cognition literature distinguishes two systems especially related to numerosity processing. The object tracking system (OTS) makes it possible to individuate and track in parallel a limited number of objects, generally up to three or four, supporting precise representations of small sets. The approximate number system (ANS), in turn, represents larger magnitudes approximately, without individuating each element, and its precision varies according to the ratio between the quantities compared, in accordance with Weber's Law (Feigenson *et al*., 2004). The perceptual configuration of stimuli also interferes with this processing: density, spacing, grouping, and visual segregation can modify set discrimination (Anobile *et al*., 2014). This study distinguishes these components from later symbolic forms of numerical knowledge and situates the OTS and ANS among the early foundations of quantitative cognition.

The initial independence of these mechanisms from language does not imply functional isolation during development. The construction of exact numerical knowledge involves the articulation of early quantitative abilities, number words, the counting sequence, one-to-one correspondence, and understanding of the cardinal principle (Carey, 2009; Marcilese, 2012). Language thus provides means to stabilize and combine representations that nonsymbolic systems alone do not encode as the natural-number system does. This interface can also operate in tasks that do not require numerals: a quantifier can linguistically define a relation to be identified in a visual scene and thereby reorganize the criterion used to select among competing quantitative configurations (Deschamps *et al*., 2015).

The relationship investigated here does not presuppose a direct correspondence between particular quantifiers and the OTS or ANS. All and some are not operators specific to small numerosities, just as many and few are not necessarily linked to sets processed by the ANS. Numerosity systems are characterized by perceptual properties and set magnitude; quantifiers introduce semantic and pragmatic relations that may apply to sets of different sizes. In the experimental design, the contrast between three or four elements and five, seven, eight, or ten elements constituted an operational classification of conditions designed to favor precise individuation and approximate estimation, respectively. This variable made it possible to verify whether the numerosity difference made an independent contribution to performance, without treating the observed behavior as a direct measure of OTS or ANS activity.

In processing terms, the task can be described as a process of integration between a linguistic representation and candidate visual structures. After the auditory presentation of the sentence, the participant had to keep its semantic-propositional representation available, delimit the relevant domain, compute the relation introduced by the quantifier, and evaluate which of the three visual alternatives satisfied that relation. Each image therefore constituted a candidate configuration for sentence verification. Accuracy recorded the outcome of this mapping between linguistic representation and visual configuration; latency, measured after the end of the auditory stimulus, recorded the interval used in the final stage of inspection, comparison, and response selection. In forced-choice tasks, these two measures are not equivalent and may reflect distinct components of perceptual and decisional processing (Ratcliff *et al*., 2018). The structure of the task itself prevents accuracy or latency from being interpreted as isolated indices of numerical ability, since both result from the integration of language comprehension, quantitative representation, visual inspection, and decision-making. This characterization corresponds to the operational definition adopted in this study.

Autism, language, and the declarative memory compensation hypothesis

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by persistent differences in communication and social interaction, associated with restricted and repetitive patterns of behavior, interests, or activities, with wide interindividual variation in their manifestation (American Psychiatric Association [APA], 2022). In the linguistic domain, this heterogeneity may involve phonology, morphology, syntax, semantics, and pragmatics, as well as differences in the integration of linguistic information with other representational modalities (Kjelgaard; Tager-Flusberg, 2001). This evidence makes it possible to characterize language processing in ASD as heterogeneous within the spectrum itself.

In the domain of numerical cognition, Meaux *et al*. (2014) identified differences in the neural substrates associated with numerosity estimation in autistic participants. This finding makes a task in which quantity judgment does not occur in isolation, but under the guidance of a linguistic sentence, particularly informative. Group differences may emerge from the interaction between the linguistic and quantitative components of the task, rather than necessarily from a global alteration in the ability to represent numerosities.

At the level of memory systems, the declarative/procedural model proposes a functional division between learning and memory mechanisms that participate differently in language processing. Declarative memory, associated mainly with medial temporal structures and the hippocampus, supports the learning and retrieval of facts, events, and arbitrary relations, including an important portion of lexical knowledge. Procedural memory, linked to frontal and basal ganglia circuits, participates in the implicit learning of sequences, regularities, and skills and, in the model, has been related to the processing of regular aspects of morphology, syntax, and phonology (Ullman, 2004). The two systems show functional overlap: linguistic structures may be learned or processed through different routes according to experience, development, and individual characteristics.

The declarative memory compensation hypothesis derives from this architecture. Ullman and Pullman (2015) propose that the flexibility of the declarative system allows it to support behaviors that, under typical conditions, would depend more heavily on procedural learning or processing. In neurodevelopmental disorders associated with reduced efficiency of procedural mechanisms, declaratively stored knowledge, associations, or strategies could support part of performance. This proposal extends to other cognitive domains, but is particularly relevant to this study in its linguistic applications, because it makes it possible to predict alternative routes for phenomena traditionally related to grammatical regularities. In Brazilian Portuguese, Bezerra (2018) obtained results compatible with this proposal in an investigation of the processing of morphologically derived words in autistic participants, although the linguistic object and experimental procedure differed from those used in the present study.

The literature on memory in ASD describes a composite profile, with variation according to the memory system, task, and participant characteristics. In reviewing the relationships among memory, learning, and language on the spectrum, Boucher and Anns (2018) question the generalization of a uniform procedural deficit and argue that the contribution of different systems depends on the task, linguistic ability, and participant characteristics. This framework does not eliminate the compensation hypothesis, but defines the empirical conditions under which it must be evaluated.

In this study, compensation was operationalized on the basis of a differential behavioral prediction. A simple increase in accuracy in conditions containing quantifiers characterizes linguistic modulation, but is not sufficient to characterize autism-specific compensation, because the same information may benefit participants in both neuroconditions. A pattern compatible with the strong behavioral formulation of compensation would require a proportionally equal or greater benefit in the autistic group, reducing the gap relative to the non-autistic group, or preserved accuracy accompanied by greater latency if task resolution depended on an alternative route with a higher decisional cost. The joint comparison of neurocondition, operator presence and type, accuracy, and latency thus provides the behavioral criterion used to examine this prediction. An explicit distinction is therefore established between linguistic modulation and declarative compensation.

Methodology

The study adopted a quantitative, comparative experimental design developed within the Language Processing Laboratory of the Federal University of Paraíba (Laprol/UFPB). The procedure was based on a psycholinguistic three-alternative forced-choice task (3AFC), a format in which the participant selects a single response from three available options. The task combined auditory and visual stimuli to examine the effect of quantifier presence and type on nonsymbolic numerosity judgments.

The final sample comprised 41 children and adolescents aged 6;0 to 15;11 years. The non-autistic group (NA) consisted of 21 participants with no reported diagnosis of ASD or another neurodevelopmental disorder. The autistic group (AT) comprised 20 participants with a formal ASD diagnosis documented by a neurologist and/or psychiatrist; 14 had support level 1 and six had support level 2, according to clinical records based on the DSM-5-TR (APA, 2022). ICD-11 diagnostic codes and DSM-5-TR support levels were recorded separately because they describe different clinical dimensions. The AT group included participants with no intellectual disability recorded in the diagnostic documentation. No independent clinical screening was conducted to exclude neurodevelopmental disorders in the NA group; its composition was based on information provided by caregivers and recruiting institutions regarding the absence of a known diagnosis. Nor was an a priori sample-size calculation performed; the final number of participants resulted from recruitment of individuals who met the inclusion criteria and completed the experimental protocol during the data-collection period.

Participants were required to understand simple verbal commands in Portuguese, recognize everyday objects and color contrasts, hear the auditory stimuli without known impairment, and have sufficient motor control to select an alternative directly on the touchscreen. Oral response production was not part of the task, allowing children and adolescents with speech limitations to participate provided that they had sufficient comprehension of the utterances. The minimum age of six years was defined because it corresponds to a developmental period in which morphological number marking is already relatively stabilized in obligatory contexts (Befi-Lopes *et al*., 2009).

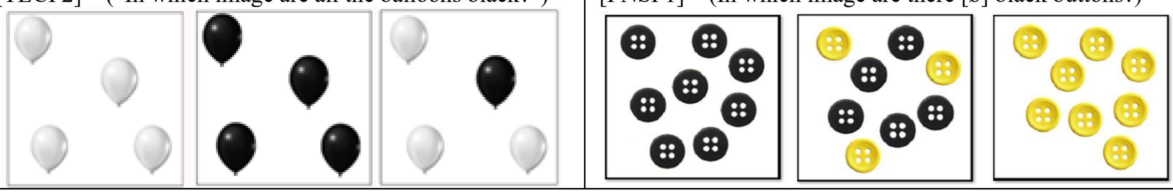
The experiment was designed as an adaptation of nonsymbolic numerosity judgment tasks used in the literature (Halberda; Feigenson, 2008), incorporating a linguistic stage prior to the visual choice. On each trial, the participant listened to a complete sentence and, after the audio ended, viewed three images presented simultaneously. One corresponded to the relation expressed by the utterance, while the other two served as contrasting alternatives. The response was recorded by directly touching the selected image.

The visual stimuli consisted of everyday objects rather than the homogeneous dot arrays frequently used in classic numerosity tasks. The spatial arrangement of the objects varied across items, and both trial order and the position of the three alternatives were randomized. The quantitative composition of each trio followed criteria defined according to the semantics of the operator. For all, for example, the incorrect alternatives represented partial satisfaction of the property and the absence of elements with the target property; in items with some, the contrasts included totality and absence; for many and few, the alternatives were constructed to produce contrasting quantitative relations between greater and lesser extension of the property. The target response was never defined simply by screen position or by the total absence of the relevant elements. This structure corresponded to the contrast system defined for the stimuli in this study.

Figure 1 – Examples of experimental stimulation

(a) Visual stimulus: estimable items, with cue, quant. All [TECP2] – (“In which image are all the balloons black?”)

(b) Stimulus: non-estimable items, without cue, quant. Few [PNSP1] – (In which image are there [ø] black buttons?)



Source: Prepared by the authors.

The quantitative relation represented in the images was controlled on the basis of two components: the total number of objects in the set and the subset of elements displaying the property mentioned in the sentence. Thus, in an item such as Which image has many black buttons?, evaluation focused on the relation between all buttons presented and those satisfying the property of being black. This procedure made it possible to visually grade totality, partial existence, greater extension, and lesser extension according to the quantifier under investigation, while keeping the relation between linguistic structure and quantitative configuration explicit. In this study, this relation was formalized by the correspondence between the nominal set and its intersection with the target property.

The experimental items crossed two conditions of linguistic-cue presence (operator present and operator absent) with two numerosity ranges. The condition designed to favor precise individuation comprised sets of three or four elements and was identified as OTS; the condition designed to favor approximate estimation comprised sets of five, seven, eight, or ten elements and was identified as ANS, following the distinction between nonsymbolic representational systems discussed by Feigenson *et al*. (2004). These labels were used as an operational classification of the stimuli. The experiment did not constitute an independent measure of OTS or ANS activation.

Eight experimental items were developed for each of the four quantifiers, totaling 32 items. For each operator, conditions with and without an explicit linguistic cue and OTS and ANS conditions were distributed. In the structure with all, cued sentences followed the pattern Which image shows all the cell phones as yellow?, while the no-operator condition retained the construction Which image shows the shoes as small? For some, many, and few, an existential construction equivalent to there is/are was used, as in Which image has some yellow pillows?; in the corresponding no-cue condition, the operator was omitted while the other sentence components were preserved. The two syntactic configurations were maintained systematically across the experimental conditions.

Of the 32 experimental sentences presented to each participant, 16 corresponded to the OTS condition and 16 to the ANS condition. Thirty-two filler items were added, each also accompanied by three visual alternatives, so that each session comprised 64 trials. The fillers served to reduce the predictability of the linguistic manipulation and were not included in the dataset used in the statistical models. The final analysis therefore comprised 1,312 experimental observations, corresponding to the 32 analyzable responses from each of the 41 participants.

Control of the experimental items included four lists of 32 sentences organized through counterbalancing so as to distribute lexical items and experimental conditions across task versions. Each participant received a single list plus the filler items, and the lists were distributed sequentially among participants. The procedure reduced systematic repetition of the same associations among noun, quantifier, and numerosity condition across the sample. This arrangement was based on a Latin-square design.

The auditory stimuli were produced using female-voice synthesis in Brazilian Portuguese and programmed together with the images in Paradigm Experiments software.

Sessions were conducted in person by the researcher in schools, homes, clinics, or university facilities, according to participant availability. The environments were organized in advance to reduce noise and the movement of people. A 15.6-inch touchscreen laptop and active noise-canceling headphones were used. Depending on the data-collection setting, the participant remained accompanied by a legal guardian or a professional already involved in their care context.

Before the experimental trials, there was a brief familiarization stage with the instructions and touchscreen response. On each trial, the auditory sentence was played in full; immediately after the audio ended, the three visual alternatives appeared on the screen. Latency timing began at that moment and ended when one of the images was touched. There was no time limit for the choice, no "I don't know" response option, and no feedback about correct or incorrect responses during the task. The program automatically advanced to the next item after recording the response.

The dependent variables were accuracy, coded as 1 for a correct response and 0 for an incorrect response, and choice latency, originally recorded in milliseconds and presented in the analyses in seconds. The temporal variable corresponds to the interval between the end of the auditory stimulus and selection of the visual alternative. Consequently, it represents the final comparison and decision stage of the task, rather than the total sentence-processing time from the beginning of its presentation. This operational definition is especially relevant to the later interpretation of the temporal results.

The predictor variables in the main analyses were neurocondition (NA/AT), operator presence (present/absent), operator type (all, some, many, and few), numerosity condition (OTS/ANS), and age group. Age was grouped into three ranges: A, 6;0 to 9;11 years; B, 10;0 to 12;11 years; and C, 13;0 to 15;11 years. Support level was examined separately within the AT group.

The analyses were performed in Jamovi, adopting $\alpha = 0.05$ and 95% confidence intervals when applicable. For accuracy, binomial logistic regression models were fitted. The first estimated the main effects of neurocondition, age group, OTS/ANS condition, operator presence, and operator type; the second added interactions between neurocondition and the other factors, allowing assessment of whether the experimental effects differed in magnitude between the NA and AT groups. The reference categories were the NA group, age group A, OTS condition, operator present, and some. Model fit was examined using deviance, AIC, and pseudo-R^2 measures.

Latency was examined using linear mixed-effects models, with a random intercept by participant to incorporate the dependence among the 32 responses produced by the same child. The first model included the fixed effects of neurocondition, age group, numerosity condition, operator presence, and operator type. The second retained the same random structure and added interactions between neurocondition and the other factors. Comparison between the models made it possible to determine whether introducing these interactions improved fit. Temporally extreme values identified during descriptive inspection were retained when there was no evidence of recording error or data-collection failure.

The complementary analysis of support levels 1 and 2 used the participant as the unit of analysis, considering the inequality between subgroups (n = 14 and n = 6) and repeated trials per child. Individual indicators were calculated for overall accuracy, median latency, performance with the operator present and absent, accuracy gain associated with the cue, and the corresponding temporal cost. Comparisons between levels were performed using the Mann-Whitney test, with Cliff's delta to estimate effect size; Wilcoxon tests examined within-group gain associated with operator presence. A complementary linear model adjusted for age group, treated as a categorical factor, was used to assess the influence of age composition on the difference in gain between levels. These procedures constituted the exploratory strategy adopted in this study.

The study was approved by the Research Ethics Committee of the Health Sciences Center of the Federal University of Paraíba (CEP/CCS/UFPB), under Opinion No. 7,599,103, CAAE No. 87257725.7.0000.5188. Legal guardians provided consent, and the children and adolescents participated after providing assent.

Results

The analysis comprised 1,312 experimental responses, corresponding to the 32 analyzable trials from each of the 41 participants (21 in the non-autistic group, NA; 20 in the autistic group, AT). Accuracy was examined using two binomial logistic regression models: the first included the main effects of neurocondition, age group, numerosity condition, and operator presence and type; the second included interactions between neurocondition and the other variables. Choice latency was analyzed using linear mixed-effects models, with a random intercept by participant. A 5% significance level was adopted.

Accuracy

The model without interactions showed a deviance of 1,164.82, AIC = 1,182.82, and Nagelkerke $R^2 = 0.489$. Neurocondition, age group, and operator presence and type contributed to the probability of a correct response, whereas the OTS/ANS condition showed no independent effect ($p = 0.827$). Operator absence reduced the odds of a correct response (OR = 0.23, $p < 0.001$), while all and many showed an advantage relative to some (both $p < 0.001$).

Table 1 – Coefficients of the binomial logistic regression model with interactions

Predictor	*B*	SE	*p*	*OR*	95% CI for OR
Intercept	−0,266	0,290	0,358	0,766	[0,434; 1,352]
Neurocondition: AT − NA	−0,784	0,393	0,046	0,457	[0,211; 0,987]
Age group: B − A	0,827	0,314	0,009	2,285	[1,235; 4,231]
Age group: C − A	0,693	0,266	0,009	1,999	[1,187; 3,366]
Condition: ANS − OTS	0,050	0,224	0,823	1,052	[0,678; 1,632]
Operator: absent − present	−2,202	0,251	< 0,001	0,111	[0,068; 0,181]
Many − some	3,219	0,337	< 0,001	25,006	[12,922; 48,389]
Few − some	0,266	0,258	0,303	1,305	[0,786; 2,165]
All − some	5,382	0,635	< 0,001	217,428	[62,684; 754,183]
AT × group B	−0,324	0,398	0,416	0,724	[0,332; 1,578]
AT × group C	0,238	0,358	0,506	1,268	[0,629; 2,558]
AT × ANS	−0,031	0,298	0,917	0,969	[0,541; 1,738]
AT × operator absent	1,304	0,322	< 0,001	3,683	[1,959; 6,926]
AT × many	−0,588	0,441	0,183	0,555	[0,234; 1,319]
AT × few	−0,013	0,361	0,971	0,987	[0,487; 2,002]
AT × all	−2,407	0,704	< 0,001	0,090	[0,023; 0,358]

Source: Prepared by the authors.

Including interactions with neurocondition improved model fit, with deviance = 1,133.85, AIC = 1,165.85, and Nagelkerke $R^2 = 0.509$; comparison between the models confirmed this improvement, $\Delta\chi^2(7) = 30.96$, $p < 0.001$. Two interactions were statistically confirmed: AT × operator absent, B = 1.304, $p < 0.001$, and AT × all, B = −2.407, $p < 0.001$. Interactions involving age group, OTS/ANS condition, many, and few were not confirmed.

The first of these interactions shows that the difference between neuroconditions varied according to the availability of the quantificational cue. With the operator absent, estimated probabilities of a correct response were virtually equivalent between groups: 51.0% in NA and 50.7% in AT. With the operator present, these probabilities rose to 78.9% and 65.4%, respectively. The estimated gain corresponded to 27.9 percentage points in the NA group and 14.7 percentage points in the AT group, representing a ratio of approximately 1.9 between the observed increases.

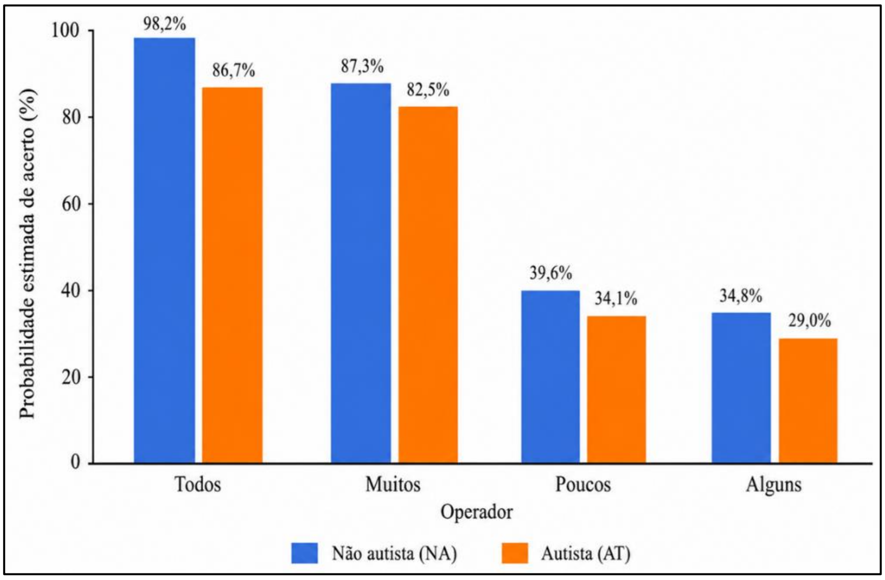
Table 2 – Estimated probabilities of a correct response by neurocondition and operator presence

Neurocondition	Operator presence	Estimated probability	95% CI
Non-autistic (NA)	Present	78,9%	[75,1%–82,7%]
Non-autistic (NA)	Absent	51,0%	[47,4%–54,6%]
Autistic (AT)	Present	65,4%	[61,0%–69,8%]
Autistic (AT)	Absent	50,7%	[46,2%–55,2%]

Source: Prepared by the authors.

The AT × all interaction identifies another concentration of the difference between groups. The general ordering of operators remained similar across the two neuroconditions, with all and many showing the highest estimated probabilities of a correct response and few and some the lowest. In the NA group, estimates were 98.2% for all, 87.3% for many, 39.6% for few, and 34.8% for some; in the AT group, they were 86.7%, 82.5%, 34.1%, and 29.0%, respectively. Considering the groups together, the probabilities were 92.4% for all, 84.8% for many, 36.6% for few, and 31.7% for some. The presence of the quantificational cue therefore produced effects of different magnitudes depending on the operator. The OTS/ANS condition remained without an independent contribution in both models.

Figure 2 – Estimated probability of a correct response by neurocondition and operator type



Source: Prepared by the authors.

Choice latency

The 1,312 responses had a mean latency of 0.32 s, a median of 0.26 s, and a standard deviation of 0.29 s. Inspection using the interquartile range identified 104 observations above the upper limit, corresponding to 7.9% of the dataset; these were retained because they did not represent identifiable data-collection failures. In the model without interactions, marginal R^2 was 0.049, conditional R^2 was 0.315, and the intraclass correlation was 0.302, indicating a substantial contribution of between-participant variability to the distribution of response times.

Operator type was the only factor with a confirmed effect on latency, $\chi^2(3) = 48.999$, $p < 0.001$. Neurocondition, $\chi^2(1) = 1.122$, $p = 0.289$; age group, $\chi^2(2) = 1.562$, $p = 0.458$; OTS/ANS condition, $\chi^2(1) = 1.659$, $p = 0.198$; and operator presence, $\chi^2(1) = 0.007$, $p = 0.936$, showed no statistically confirmed effects. Estimated times were virtually identical with the operator present (0.322 s) and absent (0.321 s). Including interactions with neurocondition did not improve fit, $\chi^2(7) = 8.256$, $p = 0.311$; the effect of operator type remained, $\chi^2(3) = 49.345$, $p < 0.001$, and the interaction between neurocondition and operator type was likewise not confirmed, $\chi^2(3) = 4.783$, $p = 0.188$.

Estimated means revealed distinct temporal profiles. All had the shortest latency, 0.257 s, followed by some, 0.303 s, many, 0.343 s, and few, 0.383 s. Comparison with accuracy shows that precision and speed did not form a single performance scale: all combined high accuracy and shorter latency; many, high accuracy and intermediate latency; few, low accuracy and the longest estimated time; and some, low accuracy and a relatively short time. The proximity between the probabilities of a correct response for some and few (31.7% and 36.6%) contrasted with the difference between their latencies (0.303 s and 0.383 s).

Exploratory analysis by support level

The internal comparison within the AT group, consisting of 14 participants at support level 1 and six at support level 2, revealed no statistically confirmed differences. Mean overall accuracy was 58.3% at level 1 and 55.2% at level 2, $U = 56.5$, $p = 0.246$, while individual median times were virtually identical, at 0.294 s in both subgroups, $U = 31.5$, $p = 0.409$.

The largest descriptive difference appeared in the use of the quantificational cue. At level 1, mean accuracy increased from 48.7% without the operator to 67.9% with the operator, corresponding to a gain of 19.2 percentage points. At level 2, the values were 53.1% and 57.3%, with a gain of 4.2 percentage points. The direct difference between gains was 15.0 percentage points, U = 59.5, p = 0.157, with Cliff's delta = 0.417. Because the subgroups had unequal age composition, a complementary analysis adjusted for age group reduced this difference to 10.6 percentage points, 95% CI [−7.1; 28.3], p = 0.223. Given that level 2 included only six participants, these results remain exploratory and require confirmation in larger samples.

Discussion

The results show that quantificational information systematically participated in numerosity judgment. Operator presence increased the probability of a correct choice, and operator type was associated with both accuracy and latency. The operational classification between smaller and larger numerosities, designed to favor precise individuation and approximate estimation, respectively, made no independent contribution to either measure. In this design, linguistic factors showed a more consistent association with performance than the operational division of stimuli into OTS and ANS conditions. Age group also contributed to accuracy, with better performance in the two older groups than in group A, without a confirmed interaction with neurocondition, characterizing a general developmental effect within the sample.

The distribution across the four quantifiers reinforces this interpretation. All and many concentrated the highest probabilities of a correct response, although for different semantic properties. All establishes exhaustivity over the relevant domain and, in the experimental alternatives, the configuration corresponding to totality was contrasted with partial or diametrically different relations, a combination that favored a highly determinate verification condition (Chierchia, 2003; Castilho, 2015). Many, although dependent on a threshold, comparison class, and context, also showed high accuracy, probably favored by the salience of the magnitude contrasts used in the images (Ramotowska *et al*., 2024). These results show that the lexical vagueness of many did not, under the conditions used, imply a higher incidence of errors.

Some and few produced similar accuracy levels, close to the level expected in a three-alternative task, but their temporal profiles differed. The minimal semantic content of some is compatible with situations in which the property also applies to the entire set, whereas the interpretation "some, but not all" depends on pragmatic enrichment (Katsos; Bishop, 2011).

Because one of the competing alternatives presented all elements with the target property, a broad existential reading could lead to a choice compatible with the minimal existential interpretation of the sentence, although divergent from the alternative designated as the experimental target. Low accuracy accompanied by relatively short latency is compatible with this possibility. Few, in turn, depends on a contextual threshold and has negative orientation, properties that may increase the demand for comparison among competing configurations (Szymanik; Zajenkowski, 2013; Deschamps *et al*., 2015). Its profile combined low accuracy with the longest latency among the four operators. Because the record preserved only the classification of responses as correct or incorrect, it is not possible to determine which alternative underlay each error.

These results also show that operators that are semantically close in a given respect need not produce equivalent behavior. Many and few share dependence on threshold and context, yet showed opposite accuracy profiles; some and few produced similar accuracy levels accompanied by distinct temporal costs. The interaction between semantic-pragmatic properties and the perceptual configuration of the alternatives therefore appears to participate in the decision, consistent with studies describing variation in the mapping between quantifiers and quantities (Ramotowska *et al*., 2024).

The absence of an independent effect of the OTS/ANS condition does not call into question the nonsymbolic representational systems described in the numerical cognition literature (Feigenson *et al*., 2004). In the procedure used, the division between sets of three or four elements and sets of five to ten elements made no independent contribution, whereas operator presence and type were associated with accuracy and, in the case of operator type, also with latency. Numerosity was evaluated in a semantically guided task in which the sentence provided the criterion used to select among three visual configurations. The OTS/ANS condition should therefore continue to be interpreted as an operational classification of the stimuli.

The comparison between neuroconditions revealed continuity in the ordering of operators and a difference in the magnitude of cue utilization. The NA and AT groups performed better with all and many and showed lower accuracy with few and some. Neurocondition therefore did not reorganize the general hierarchy among quantifiers. The difference became more evident when the quantificational cue was available: without an explicit operator, estimated probabilities were 51.0% in the NA group and 50.7% in AT; with the operator, they reached 78.9% and 65.4%, respectively. Because sentences without a quantifier still required language comprehension and matching with the images, this contrast concerns specifically the contribution of explicit quantificational information.

The AT group also benefited from the cue, with an estimated 14.7-percentage-point increase in accuracy. The NA group showed a 27.9-percentage-point gain, approximately 1.9 times greater, widening the difference between neuroconditions in conditions with an operator. All showed the greatest separation: the estimated probability reached 98.2% in the NA group and 86.7% in the AT group, and it was the only operator whose interaction with neurocondition was statistically confirmed. The high accuracy of the AT group argues against an interpretation of generalized difficulty with all; the result points to a quantitative difference in the magnitude of the benefit associated with this cue under the experimental conditions.

The latency analysis complements this picture. Operator presence, although it increased accuracy, did not alter choice time in a statistically confirmed manner. Neurocondition likewise showed no independent temporal effect, and no interaction with the experimental factors was supported in the mixed models. Operator type remained the only factor consistently associated with latency. Quantificational information appears to have contributed mainly to defining the semantic criterion used in response selection, without producing a general acceleration of the decision stage. The temporal measure began after the audio ended and therefore corresponds to the final phase of inspection, comparison, and choice, leaving outside the recorded window the processes occurring during auditory sentence comprehension.

Integrating accuracy and latency makes it possible to evaluate the declarative memory compensation hypothesis in the behavioral terms defined for this study. A pattern compatible with its strong formulation would involve equal or greater benefit in the AT group from linguistic cues, with convergence in accuracy between neuroconditions, or preserved accuracy associated with greater latency if an alternative route supported the response at a higher temporal cost. Neither pattern was observed. Quantificational information benefited autistic participants, but to a lesser extent than non-autistic participants, and the temporal models revealed no differential cost associated with neurocondition.

The procedure did not directly measure declarative memory or procedural learning; therefore, the conclusion concerns the compatibility between the observed behavioral pattern and the prediction derived from Ullman and Pullman (2015). This compatibility was not confirmed in the strong formulation examined: the cue benefited the AT group to a lesser extent, and there was no evidence of a differential temporal cost associated with preserved accuracy. Findings favorable to compensation have been reported in other linguistic domains, such as the morphological processing investigated by Bezerra (2018), while Boucher and Anns (2018) describe considerable variability across tasks and memory profiles in autism. The contribution of declarative memory to linguistic performance may therefore vary according to the linguistic operation, task demands, and participant characteristics.

The analysis by support level showed a similar direction. Levels 1 and 2 did not differ statistically in overall accuracy, latency, or gain associated with operator presence. The largest descriptive contrast appeared in accuracy gain, at 19.2 percentage points in level 1 and 4.2 percentage points in level 2, a difference that was likewise not confirmed after adjustment for age group. Interpretation of these values remains conditioned by the size of the level-2 subgroup and unequal age composition. Support level describes clinical-functional needs and is not a direct measure of linguistic competence, numerical cognition, or memory-system functioning (APA, 2022).

Several features of the design guide the next steps of the investigation. Declarative and procedural memory were not assessed with independent instruments; the NA group was defined by the absence of a reported diagnosis of neurodevelopmental disorders, without independent clinical screening; the sample included participants aged 6 to 15 years, a range encompassing distinct stages of linguistic and attentional development, although age was incorporated into the models as a control factor; latency began only after the utterance ended; and error recording did not preserve the selected alternative, information that would make it possible to distinguish different sources of incorrect responses, particularly for some. The proportions and visual contrasts used may also have favored certain operators, such as the high discriminability of all and the quantitative salience of many. Future studies may combine independent memory measures with records of processing during sentence comprehension, using eye tracking, electrophysiological measures, or equivalent temporal procedures. Explicit manipulation of the implicature of some, the thresholds of many and few, and the proportions between sets would make it possible to separate semantic-pragmatic effects more precisely from those related to the visual composition of the stimuli.

The four quantifiers produced distinct combinations of accuracy and latency, although the general ordering of these profiles remained similar across the two neuroconditions. In studies of linguistically mediated numerosity, the identity and semantic-pragmatic properties of the operator constitute part of the experimental condition itself, rather than an interchangeable lexical variation.

Final considerations

This study examined the effect of the quantifiers all, some, many, and few on nonsymbolic numerosity judgments in autistic and non-autistic children and adolescents. The prediction of linguistic modulation was supported mainly by accuracy: the presence of the quantificational cue increased the probability of a correct response, while operator type distinguished performance in both accuracy and latency. The operational OTS/ANS condition independently explained neither measure.

The groups preserved the same general ordering among quantifiers, although they differed in the magnitude of the benefit obtained from the cues. Operator presence produced a greater gain among non-autistic participants, and the difference between neuroconditions was concentrated especially in all. Quantificational information was also associated with higher accuracy in the autistic group; however, this benefit did not show the distribution predicted by the strong behavioral formulation of the declarative memory compensation hypothesis.

The data showed neither convergence between groups when the linguistic cue was available nor a pattern of greater temporal cost associated with preserved accuracy in the autistic group. The compensation hypothesis, in the behavioral terms examined, was not supported in this study. The specific participation of declarative and procedural memory remains a question to be investigated through independent measures of these systems.

The findings place linguistic quantification as a relevant component of numerosity judgment and show that all, some, many, and few establish distinct accuracy and latency profiles. Future investigations should more directly separate the effects of the semantic-pragmatic properties of the operators, the perceptual organization of the alternatives, and individual differences in language and memory, including through independent measures of declarative and procedural systems.

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