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Relationships between Area and Perimeter by Students with the Autism Spectrum Disorder. An Exploratory Study

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ABSTRACT

Background: One of the difficulties that appear systematically in learning the geometric quantities area and perimeter is associated with the intuitive idea of the existence of a relationship of dependence between the two. This difficulty is common to students of different ages and has been analysed in contexts of typical development. **Objective:** To investigate what happens to students with autism spectrum disorder (ASD) when they are presented with activities involving the concept of perimeter and area. **Design:** A qualitative and exploratory methodology was used, specifically, a case study. A specific geometry test consisting of a semi-structured interview and an ad hoc test was designed and validated. **Setting and Participants:** The sample consisted of three students, two in fourth grade and one in sixth grade, all of them diagnosed with ASD and with an IQ above 80 points on the WISC-V scale. **Data collection and analysis:** The written productions and the semi-structured interviews were analysed and triangulated according to the categories of Avila and Garcia (2020). **Results:** All the children affirm that there is no dependency relationship between area and perimeter when area remains unchanged, but two describe a dependency relationship when perimeter remains constant. The requirement to exemplify their answers has helped them to realise their error. **Conclusions:** A guided intervention focused on the teacher's request to specify the answers through examples has helped to improve the understanding of these concepts and presents lines of future research associated with the creation of teaching practices for this type of students.

Keywords: Area; Perimeter; Autism spectrum disorder (ASD); Intuition; Primary education.

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Relaciones entre área y perímetro por estudiantes con trastorno del espectro autista. Un estudio exploratorio

RESUMEN

Contexto: Una de las dificultades que aparecen de modo sistemático en el aprendizaje de las magnitudes geométricas área y perímetro es la asociada a la idea intuitiva de la existencia de una relación de dependencia entre ambas. Esta dificultad es común a alumnado de distintas edades y ha sido analizada en contextos de desarrollo típico. **Objetivo**: Indagar qué sucede con estudiantes con Trastorno de Espectro Autista (TEA) cuando se les plantean actividades que involucran el concepto de perímetro y área. **Diseño**: Se ha llevado a cabo una metodología de corte cualitativo y tipo exploratorio, en concreto, un estudio de casos. Se ha diseñado y validado una prueba de geometría específica consistente en una entrevista semiestructurada y un test ad hoc. **Método y participantes**: La muestra consta de tres estudiantes, dos de cuarto curso y otro de sexto, todos ellos diagnosticados con TEA y con un CI superior a 80 puntos en la escala WISC-V. **Recolección de datos y análisis**: Las producciones escritas y las entrevistas semiestructuradas se han analizado y triangulado acorde a las categorías de Ávila y García (2020). **Resultados**: Todos los niños afirman que no hay relación de dependencia entre el área y el perímetro cuando es el área quien se mantiene invariable, pero dos de ellos sí describen una relación de dependencia cuando el perímetro se mantiene constante. El requerimiento de ejemplificar sus respuestas les ha ayudado a darse cuenta de su error. **Conclusiones**: Una intervención guiada centrada en la solicitud de concreción de las respuestas por medio de ejemplos por parte del profesorado ha ayudado a mejorar la comprensión de estos conceptos y presenta líneas de investigación futuras asociadas a la creación de prácticas docentes para este tipo de alumnado.

Palabras clave: área; perímetro; Trastorno del Espectro Autista (TEA); intuición; educación primaria.

Relações entre área e perímetro por alunos com transtorno do espectro autista. Um estudo exploratório

RESUMO

Contexto: Uma das dificuldades que aparecem sistematicamente na aprendizagem das grandezas geométricas área e perímetro está associada à ideia intuitiva da existência de uma relação de dependência entre os dois. Essa dificuldade é comum a alunos de diferentes idades e tem sido analisada em contextos de desenvolvimento típico. **Objetivo:** Investigar o que acontece com alunos com Transtorno do Espectro Autista (TEA) quando recebem atividades que envolvem o conceito de perímetro e área. **Design:** Foi realizada uma metodologia do tipo qualitativa e exploratória, especificamente, um estudo de caso. Foi elaborado e validado um teste específico de geometria composto por uma entrevista semiestruturada e um teste ad hoc. **Ambiente e Participantes:** A amostra é composta por três alunos, dois da quarta série e um da sexta série, todos com diagnóstico de TEA e com QI superior a 80 pontos na escala WISC-V. **Coleta e análise de dados:** As produções escritas e as entrevistas semiestruturadas foram analisadas e trianguladas segundo as categorias de Ávila e García (2020). **Resultados:** Todas as crianças afirmam que não há relação de dependência entre a área e o perímetro quando é a área que permanece constante, mas duas delas descrevem uma relação de dependência quando o perímetro permanece constante. A exigência de exemplificar suas respostas os ajudou a perceber seu erro. **Conclusões:** Uma intervenção orientada e focada na solicitação de respostas específicas por meio de exemplos por parte dos professores tem ajudado a melhorar a compreensão desses conceitos e apresenta linhas de pesquisas futuras associadas à criação de práticas pedagógicas para esse tipo de aluno.

Palavras-chave: área; perímetro; Transtorno do Espectro Autista (TEA); intuição; Ensino Fundamental.

INTRODUCTION

Today, we must have different skills that help us tackle daily tasks successfully. Many of them are linked to mathematical competence, understood as “the ability of people to formulate, use and interpret mathematics in different contexts” (OCDE, 2017, p.64). For a positive response from education to this challenge, different international entities have established standard parameters to evaluate the level of competence of a person, among which the PISA test stands out. It establishes four categories of content to group a large part of the mathematical knowledge an adult must have to develop critical and reflective thinking before situations requiring mathematical modelling for their resolution.

Within the four categories, this article focuses on the one named “space and form”, which encompasses activities and skills associated with interpreting our visual and physical environment. Geometry and measurement are part of this category.

In measurement, many investigations have tried to analyse problems associated with the understanding, knowledge, and interpretation of different magnitudes, especially those related to the determination of unambiguous characteristics of flat shapes and objects in space. From a mathematical point of view, these magnitudes are nothing more than functions of the Euclidean space to the set of real numbers: for each closed shape of R^2, a real positive value is established. Thus, we find two functions, the perimeter and the area, which associate a real value for each given shape. These same concepts can be generalised for each closed object of R^3, when possible, leading to the length of the edges, the lateral area, the total area, and the volume of the object.

This relationship established between R^3 and R by means of functions allows us to characterise objects not only by their shape but also by their measure, thus establishing other possible ways of classification or identification.

In this sense, one of the classic problems is the one associated with trying to establish possible relationships between different kinds of magnitudes of a form or an object that allow calculating some measures based on the knowledge of others. This problem arises from the erroneous interpretation that since they are measures associated with the same object, they could be somehow linked. An example of this problem is the case of the perimeter and the area. As we will see below, many studies were centred on determining the intuitive ideas held about the perimeter and the area or about the conceptual errors associated with possible relationships between these two magnitudes. These studies have focused mainly on primary school students, secondary school students, and primary school teachers. However, when we concentrate on students with special learning needs, we find that few investigations show what happens to these research questions. Therefore, in this work, which is part of a broader study approved by the Cantabria Ethics Committee for Clinical Research (code 2020.252), we intend to analyse what happens in the teaching-learning process of the area and the perimeter with primary education children with autism spectrum disorder. That is, we intend to see their intuitive ideas about the perimeter and the area, see the type of relationships that they intuitively believe exist between both magnitudes, and analyse the impact that a sequence of activities designed to work these concepts has on these intuitive ideas.

THEORETICAL FRAMEWORK

When addressing the learning-teaching process of mathematics in basic education (6 to 12 years), one of the sections we find in all international educational curricula refers to measure, a section that requires a comprehensive approach to the magnitudes and their properties. In the case of Spain, from the first year (6 years), progressive learning is proposed, first with the use of different units of measurement to estimate and measure, and second, addressing the treatment of more complex magnitudes, such as the perimeter and the area and the resolution of mathematical problems associated with them (Bloque 3, Real Decreto 126/2014, February 28).

This educational approach requires us to identify the properties of objects that are measurable and differentiate them from those that are not. This ability helps to recognise characteristics (mainly metrics) of space and its relationships and makes a close connection between measurement and geometry. This connection implies that many of the learnings associated with geometry fall back on understanding measurement processes, and these, in turn, lead to difficulties associated with measurement (De Gamboa, Badillo, & Ribeiro, 2015).

In the case of measurement in the Euclidean plane, the treatment of the perimeter and area magnitudes stands out. In this context, research has focused on three issues: 1) analysing the ideas associated with the area and the perimeter; 2) establishing the reasons for the difficulties associated with the alleged dependency relationship between area and perimeter; 3) establishing what educational tools can help to overcome these learning errors and to what extent.

Regarding the first line of research, some studies indicate that one of the difficulties on the part of the students is the confusion between the area and perimeter concepts themselves (Douady, 1988; Silva, 2009). Thus, Dickson, Brown and Gibson (1991, cited in Nortes Martínez-Artero and Nortes-Checa, 2013) determine how, in measurement contexts, school-age children confuse these two magnitudes, adjudging incorrect measurements to examples of known geometric figures.

Özerem (2012), in a study with 7th-grade students, again concludes that some continue to make mistakes when calculating areas of basic polygons, such as the triangle or parallelograms, incorrectly using the corresponding formulas.

Regarding the second line of research, establishing the reasons for the difficulties associated with the alleged dependency relationship between area and perimeter, several investigations point out that the error lies in the difficulty of separating the two concepts or in the lack of understanding of each of them.

Douady and Perrin (1988, cited in Ávila & García, 2020) show how children establish a dependency relationship between the perimeter and the area, concluding that the most common relationship is that the increase of one of them necessarily implies the increase of the other.

Stavy and Tirosh (1996) establish that one of the reasons that generate the errors associated with the understanding of mathematical concepts, a priori very different, lies in the intuitive idea “the more of A, the more of B”, which gives rise to important learning errors in different areas of mathematics; which, in the case of the area and the perimeter, leads to the error “if A has a greater perimeter than B, then A has a greater area than B”.

D'Amore and Fandiño-Pinilla (2007) show how this misconception ("if A has a greater perimeter than B, then A has a greater area than B") is still valid in learning contexts in classrooms at different educational stages and, in particular, implies the false idea of a dependency relationship between the perimeter and area of a flat figure. These authors conclude as possible causes not only epistemological reasons but also questions of didactic nature when these concepts are addressed in the classrooms, proposing possible activities that help their better understanding.

Machaba (2016) concludes that 10^{th}-grade students do not have a conceptual understanding of the area and do not know what the perimeter is. Also, that they have misconceptions about the relationship between area and perimeter and proves that these errors are due to inadequate prior knowledge of the area and the perimeter.

Regarding the third line of research, establishing what educational tools can help students overcome these learning errors and to what extent, several studies have been carried out, with different approaches.

Thus, Ávila and García (2020) delve into the need to understand why children aged 9 to 12 have initial intuitions regarding the possible relationships between perimeter and area. Likewise, they affirm that with students with high performance at school, a learning sequence with a geometric approach can be a useful tool for the development of their mathematical thinking.

Mantica et al. (2002) propose classroom activities with students aged 13-14 years in order to make them understand the independence between the area and the perimeter, concluding that, despite these classroom activities, students tend to compare the length of the sides of the figures when obtaining the areas.

García-Amadeo and Carrillo (2006) analyse how, starting from a didactic unit based on problem solving to build the concept of area for the 5^{th} grade of primary education, cognitive and sociological aspects naturally emerge in a girl's reasoning, aspects that are interwoven and complementary in the understanding of the independence between area and perimeter.

When we refer to students with learning disabilities (LD), despite the fewer studies, we find previous work that has addressed some of the problems above.

Thus, Kozulin and Kazaz (2017) analyse the influence of better understanding the concept of measurement when understanding the perimeter and the area to develop successful tasks associated with their learning.

In length contexts, Güven, and Argün (2018) analyse the conceptions associated with this notion in their different representations (width, length, and height) of three children with LD in 4th, 5th, and 6th grades, concluding that the ideas associated with length, width, and height are influenced by those established for length and visual-spatial capacity. In addition, Güven and Argün (2021) affirm that 4th and 5th-grade LD girls and boys have a different and limited understanding in learning situations involving length, making use of limited language, with difficulties in technical terms such as length, height, perimeter, half, and centimetre.

Regarding the third line of research, different investigations have focused their interest on seeing which interventions for students with LD are successful and in what sense.

Cass, Cates, Smith, and Jackson (2003) analyse that, to solve problems of areas and volumes in secondary education successfully, the use of concrete manipulative materials is fundamental in classroom practice because it promotes the acquisition of long-term skills. Likewise, Satsangi and Bouck (2015) demonstrate that using virtual manipulative materials is an effective tool for acquiring, understanding, and generalising the concepts of area and perimeter.

Hord and Xin (2015) analyse the implications of an instructional sequence based on "concrete-semiconcrete-abstract" (CSA) and modelling-based learning in the resolution of problems of areas and volumes in the 6th grade, concluding that this helps to improve the achievement of the tasks posed in a high percentage, but is not sufficient for the resolution of problems with the expected complexity at this level.

Finally, if we focus our interest on people with autism spectrum disorder (ASD), we must first understand some of the characteristics that define this group, as follows: alterations in social behaviour and interests, stereotyped and repetitive use of language, use of idiosyncratic language, alteration of language understanding due to difficulty in understanding questions or instructions, echolalia, and problems of selective attention to language (Franco Justo & Andrés, 2001). Dolz (1994) points out that there is a gap between the development of written *vis-à- vis* oral argumentation skills, stating that a girl or boy is able to defend his/her point of view in an oral argumentative dialogue with less difficulty than in written form.

Thus, despite the educational interest that would imply better understanding the geometric reasoning of people with ASD, we must mention that previous research is scarce (e. g. Santos et al., 2020; López de la Fuente et al., 2020; Widayati et al., 2017); For example, Widayati et al. (2017) analyse the learning of geometry in autistic children in the 1st and 2nd grades of high school, concluding the importance of the teacher's guide to facilitate the concentration of these students. But as far as we know, no studies analyse the difficulties of boys and girls with ASD when facing measurement tasks that involve the use of geometric magnitudes.

METHODOLOGY

This study is qualitative and exploratory (Yin, 2017). Qualitative research aims not only to describe and understand the reality it studies but also to explain it, i.e., to propose the "why" of the observed facts (Del Gallego & Álvarez, 2013). Specifically, this is a case study, a research approach that facilitates the exploration of a phenomenon using various data sources, ensuring that the problem is analysed from different perspectives (Baxter & Jack, 2008).

Research questions

Through this research, we propose to approach the intuitive idea shown by three primary education students diagnosed with ASD about the concepts of perimeter and area and the relationships they establish between these two magnitudes. Specifically, we ask the following research questions: (1) What intuitive idea do three primary education students with ASD show about the concepts of area and perimeter? (2) What initial intuitive idea do they show about whether there is a relationship that links area and perimeter, and what modifications does this initial intuitive idea undergo after carrying out activities related to the measurement of these magnitudes?

Participants

The participants were three male students diagnosed with ASD enrolled in different regular schools in a Spanish province: two were in the 4th grade (E1 and E2), and one was in the 6th grade of primary school (E3). The three students were part of a larger study on mathematical problem solving, approved by the Cantabria Clinical Research Ethics Committee (code 2020.252). Participation was voluntary, and all data protection requirements were met. The following table shows the main characteristics of these participants: grade in which they were enrolled, chronological age, direct score out of 72 according to the TEMA 3 test (Ginsburg & Baroody, 2007), equivalent mathematical age (measured from the direct score), and IQ measured by WISC-V (Weschler, 2015). The TEMA 3 instrument only includes equivalence for mathematical ages up to nine years, and the ages are expressed in years:months.

Table 1

Data of the participants in the investigation.

Student	Course	Chronological age	Score Direct (TEMA-3)	Mathematical age equivalent	CI (WISC-V)
E1	4th EP	9:3	39	6:4	88
E2	4th EP	9:2	46	6:10	99
E3	6th EP	11:1	71	>9:0	112

Task sequence

After a curricular review through the Royal Decree 126/2014, of February 28, which establishes the basic curriculum of primary education and after consulting several primary education textbooks, a geometry test consisting of a semi-structured interview and an ad hoc test is built and validated (López de la Fuente, 2020). For this study, ten questions associated with the measurement of perimeter and area magnitudes were selected from the test and are detailed below:

Activity 1.

Activity 1.1. What would you say is the perimeter of a figure?

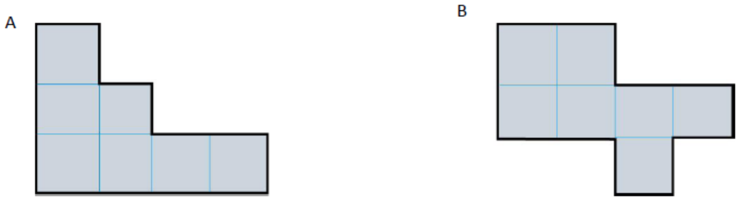
Activity 1.2. What would you say is the area of a figure?

If the students did not answer questions 1.1 and 1.2, or showed need for help in answering, the following story (authors' own elaboration) would be read to them. The character wearing a P on the shirt is called Perimeter, and his job is to close the zone with fences. The character wearing an A is called Area, and his job is to fill that zone with square tiles.

Look at these figures (see Figure 1)

Figure 1

Figures used for activity 1.3 and 1.4 (Goñi Zabala, 2003)

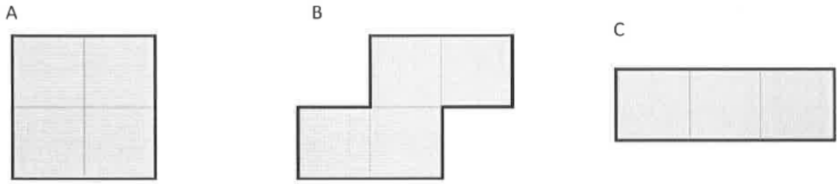


1.3. What is the perimeter of Figure A? What is the perimeter of Figure B?

1.4. What is the area of Figure A? What is the area of Figure B?

Figure 2

Figures used for activity 2 (Almodóvar, García Atance & Pérez Saavedra, 2012)



Activity 2. Look at these figures (see Figure 2)

2.1. Do you think that two different figures can have the same area, but different perimeter?

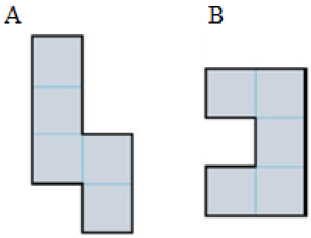
2.2. Do you think that two different figures can have the same perimeter, but different area?

2.3. Draw the necessary figures to justify your answers.

Activity 3. Look at these figures (see Figure 3). Draw a figure with 5 "little squares" of area that is different from the figures above.

Figure 3

Figures used for activity 3 (Arribas, 2008; López de la Fuente, 2020)



Activity 4.

4.1. Build a polygon by joining 9 squares that have the smallest possible perimeter.

4.2. Also, build another polygon with 9 squares that has the largest possible perimeter.

Achievement objectives and research objectives associated with the sequence

Table 2 shows the achievement objectives and the research objectives with which we relate each of the proposed activities.

Table 2

List of activities and research objectives

Activity No.	Achievement objective	Research objective
1.1.	Definition of perimeter	1
1.2.	Definition of area	1
1.3.	Calculation of the perimeter of figures	1
1.4.	Calculation of the area of figures	1
2.1.	Intuitive idea about area-perimeter relationship	2
2.2.	Intuitive idea about area-perimeter relationship	2
2.3.	Exploration of the intuitive idea of area-perimeter relationship through concrete examples	3
3	Exploration of the intuitive idea of area-perimeter relationship through concrete examples	3
4.1.	Construction of a polygon of area 9 and minimum perimeter	1, 2, 3
4.2.	Construction of a polygon of area 9 and maximum perimeter	1, 2, 3

Activities 1, 2 and 3 are common to all courses, while activity 4 is only for participants attending the 5^{th} or 6^{th} grade of primary education. Therefore, only one student (E3) had to work on this last activity.

The test was conducted through a semi-structured interview. The interviewer had a script with possible questions, which also included some set phrases or suggestions for the application of the interview. For example, the interviewer's guide indicated that it was necessary to insist that students explain their reasoning with questions such as, "How did you calculate the area? How did you calculate the perimeter? (Activity 3)", "How did you think about making the figure with the smaller perimeter? (Activity 4)". All sessions were videotaped and transcribed, and each participant's verbal and written answers were analysed in detail.

Categories of analysis

In the questions in which a definition of area and perimeter and its calculation are required, we analyse whether the children can give a definition associated with area and with perimeter or if they do not do it correctly (Douady, 1988). In this case, we check whether they do not distinguish these two concepts correctly or if they mix them both.

In the questions in which the participants are asked whether there is a relationship between the area and the perimeter, as per Ávila and García (2020), we establish the following categories for classifying the students' answers. In particular, we distinguish between the answers that establish dependency or independence between the two magnitudes.

The answers that affirm a dependency between perimeter and area show the conviction that when one of these magnitudes varies, the other also varies. The answers that maintain an independence between perimeter and area reveal the conviction that two figures may have the same perimeter but different area, or the same area but different perimeter.

Within the above categories, we distinguish between the following types of answer:

(1) **Without justification**: the answer is not justified; it is answered without an explanation. For example: "Completing the area (does not) force you to add more perimeter" or "I know because it's obvious".

(2) **Justification based on examples**: the participant justifies the answer based on examples. For example, two figures are created, and both the perimeter and the area are measured to show the conviction of dependency or independence between the magnitudes.

(3) **With justification with other arguments**: the participant justifies the answer basing it on other arguments. A reasoning that does not resort to concrete examples to argue dependency or independence is expressed. For example, the formula for finding the area is related to the formula for finding the perimeter and dependency or independence between the magnitudes is established. Another example of an argument: "with more corners, the space is smaller".

RESULTS

Next, we present the results by dividing them into the following parts: (1) the initial intuitive idea about area and perimeter (activity 1), and (2) the area-perimeter relationship (activities 2, 3, and 4).

Intuitive idea about area and perimeter

During the test application, students showed different intuitive ideas regarding the perimeter and area magnitudes. The following table summarises the main ideas of each participant in relation to both magnitudes.

Table 3

Intuitive ideas about perimeter and area of the three students.

Student	Intuitive ideas about the perimeter	Intuitive ideas about the area
E1	"The lines surrounding the figure"	"The filling of a figure" "All tiles together" [Marks and lines inside the figures]
E2	"Counting what's outside."	"What's inside the perimeter"
E3	"The shape of a figure without filling"	"The filling of the perimeter of a figure"

Below, we describe in detail the course of the interviews with the interviewer of each student where these ideas were revealed.

Student E1

E1 was interested in geometry and mathematics at the beginning of the test. He was participatory, in general, and, although during the test he asked several times how many questions were left, or looked tired, he answered all them all.

At the beginning of the test, E1 reported not knowing what the perimeter or area of a figure was. When the interviewer read him the story selected for these questions, E1 expressed his idea of the concepts perimeter and area by making drawings. The conversation between the interviewer and E1 is transcribed below:

> *INT: So, what would you say is the perimeter? If someone asked you, what would you say? The perimeter of a figure…*
>
> *E1: [Makes a drawing (see Figure 4, left)]*
>
> *INT: And in words, how would you put it?*
>
> *E1: I don't know… [thinks] The lines surrounding a figure.*
>
> *INT: Okay, the lines surrounding a figure.*
>
> *And, what would you say is the area of a figure?*
>
> *E1: [Makes a drawing (see Figure 4, right)]*
>
> *INT: Very good, and, in words, how would you put it?*
>
> *E1: Well... the filling of a figure.*

Figure 4

Idea of perimeter (left) and area (right) by E1

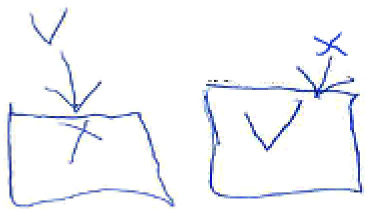
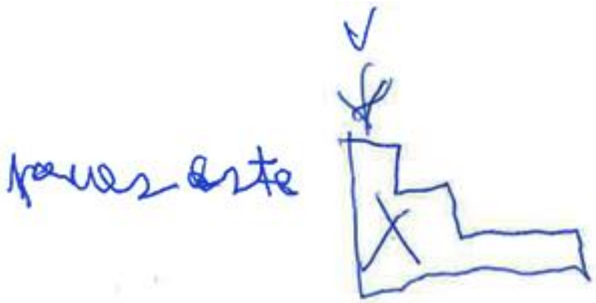


Figure 4, left, shows how E1 indicated by an arrow and a tic (V) that the border of the figure is the perimeter. And thus he expressed it when he was encouraged: "the lines that surround a figure". Figure 4, right, shows how the student indicated that the area is the filling while indicating with an arrow and a cross (X) that the borders would not fit into this concept. In addition, he expressed it thus: “The area is the filling of the figure”.

The interviewer then showed E1 Figures A and B from the next activity (see Figure 1) and asked him to find out their perimeter. E1 again resorted to drawing and replicated Figure A, marking a cross on the inside, and an arrow on the top outside. He wrote: “well, this one” (see Figure 5).

Figure 5

Perimeter of Figure A by E1



The interviewer then asked him to express it in words, to which E1 replied: “Well... [the perimeter] is the part that surrounds the figure”.

Figure 6

Area of Figures A and B. By E1

When asked about the area of the given figures (activity 1.4), E1 pointed to the inside of the figure and explained: "Well, the filling. All together. All the tiles together". Then, E1 marked the inside of the figures with the pen (see Figure 6).

Figure 6 shows the marks that E1 made on the figures to show that that area was the requested area. In addition, E1 added: "As the figure itself is surrounded by perimeter… the area is what is inside the perimeter". It is remarkable that E1 did not count the number of squares in each figure but answered by providing the amount in the sense of occupied space, and not the numerical result of a measurement.

Student E2

During the test, E2 seemed comfortable, answered all the questions, and sometimes required assistance from the interviewer.

When the interviewer asked him about the concept of perimeter, E2 reported not knowing its meaning. After reading him the story selected for these questions (see observation of activity 1.2), and as E2 continued to show confusion, the interviewer asked him to calculate the perimeter of figure A (see Figure 1). The following fragment shows their conversation:

> *INT: Look, let's do it on these figures [pointing out the figures of activity 1.3] We have said that the perimeter are the fences. So, what would be the perimeter of figure A?*
>
> *E2: [Counts the squares that make up figure A one by one, hitting each with the pen] Seven... is it called perimeter?*
>
> *INT: Seven. Why?*
>
> *E2: Because there are 7 squares.*
>
> *INT: Are you counting the ones inside or the ones outside?*
>
> *E2: Ah, those inside.*
>
> *INT: Aaah, and those inside, what were they?*
>
> *E2: The tiles.*
>
> *INT: The tiles, right? And the tiles, who put them?*
>
> *E2: The ... Area*

INT: So?

E2: [Counts the perimeter one by one, following the border of the figure with the pen] Fourteen.

INT: Okay, so you're saying that the perimeter of figure A is fourteen. [..] So, the perimeter, what would you say it is? In your own words. How would you explain it to a child who doesn't know?

E2: To a child?

INT: Yes.

E2: [thoughtful] I don't know

*INT: So that the child understands it as you have understood it. Imagine a child that comes and asks you, "**Name, what is the perimeter?"*

E2: [Thinks] Mmm, what is the perimeter?

INT [nods]: Just think about what you've done here [Statement 1.3].

E2: [thoughtful, looking at the interviewer] Counting the outside.

INT: That's it.

E2: No?

INT: Yes. Then write it here.

E2: [Writes: "count the outside"]

Similarly, the interviewer guided E2 in the questions related to the concept of area.

INT: What would you say is the area of a figure?

E2: The area? [E nods] Mmm... I don't know.

INT: Remember the A character. A from Area. What was he doing?

E2: Moving the... the perimeters. Oh! The tiles. [INT nods] And... Perimeter put the...

INT: The outside, right? the fences. [E2 nods] So, to calculate the area of figure A, what would you do?

E2: Count

INT: Count, what?

E2: Everything [counting the squares by tapping each with the pen] Seven

*INT: "That's it, **Name, so, what is the area of a figure?" How would you explain it?*

E2: Hmm [thoughtful] Well… what is the area of figure B, right?

INT: No, what is the area of a figure, of any figure.

E2: Of any figure?

INT: Yes, you have calculated it very well in the A, you have said that it is 7; but what is the area?

E2: The area...

INT: In general, the area of a figure...

E2: The perimeter...

INT: You've already told me about the perimeter. Now I'm asking you about the area.

E2: I's the inside of the perimeter

INT: That's it, very good, write it here [pointing to the space of the answer in activity 1.2.]

E2: [Writes: "what is within the perimeter"]

To understand the concepts of perimeter and area E2 had already calculated these magnitudes referring to figure A (see Figure 1, left), in activities 1.3. and 1.4. The interviewer only asked him to calculate the perimeter and area of figure B (see Figure 1, right).

To calculate the perimeter, E2 counted the unit segments of the given figure one by one, making marks with the pen for each of them. He started at the top left, counterclockwise, and, at the end, replied: "fourteen". To calculate the area, E2 counted the "little squares" of which the figure was composed by tapping each square with the pen, without following a clear route. At the end, he repeated the count and finally wrote: "seven".

Student E3

E3 showed himself very determined throughout the test, hardly needed the intervention of the interviewer and, on occasion, read and answered the written questions independently.

So, E3 answered the question "What would you say is the perimeter of a figure?" (Activity 1.1.), in writing (see Figure 7).

Figure 7

E3's statement

Similarly, he answered the question about the concept of area (activity 1.2.) by writing: "[the area] is the filling of the perimeter of a figure". When the interviewer asked him, in activity 1.3., to find out the perimeter of the figures given (see Figure 1), E3 declared that he did not know what she meant by "calculating the perimeter". The interviewer encouraged him, comparing the perimeter with the fences (a spinoff of the story devised for activity 1.3.), E3 said: "this", while with his finger he went over the outline of figure A (see Figure 1, left). The student did not provide a numerical result. The interviewer then asked him how he would calculate the area, to which E3 answered: "by counting the little squares". He then counted the squares of Figure A (see Figure 1, left), and the sides of the two figures given (see Figure 1), providing the correct numerical results with respect to the two measurements.

Intuitive idea about the relationship area-perimeter

Table 4 summarises each student's answer to each of the questions.

Table 4

Students' answer according to independence or dependency manifested between magnitudes, and type of argument.

Activity	E1	E2	E3
2.1 (=A,<>P)	Independence (Unjustified)	Independence (Examples)	Independence (Other arguments)
2.2 (=P, <>A)	Dependency (Other arguments)	Independence (Other arguments)	Dependency (Other arguments)
2.3 (both)	Unanswered	Independence (Examples)	Independence (Examples)
3(=A,<>P)	Independence (Examples)	Independence (Examples)	Independence (Examples)
4.1(=A,<>P)			Independence (Examples)
4.2(=A,<>P)			Independence (Examples)

Next, we will detail the performance of each of the students.

Student E1

To perform activities 2.1., 2.2. and 2.3. the interviewer showed E1 some figures (see Figure 2) and allotted him some time to observe them. The interviewer then asked, "Do you think two different figures can have the same area, but different perimeter?", to which E1 answered, "Yes, yes." We interpret that he established *independence between perimeter and area*, and the answer is classified as*: without justification* since the student did not provide any explanation. The interviewer encouraged him to explain his answer, and E1 added: "Obviously... it can be... it is that the area, no, the perimeter... does not affect the area."

Despite maintaining independence between perimeter and area of two figures of the same area, E1 did not transfer that belief when the constant magnitude was the perimeter. The dialogue between the interviewer and E1 on this occasion was:

> *INT. Do you think that two different figures can have the same perimeter, but different area?*

E1: No, no. [Writes "no"].

INT: Why?

E1: Because... because the perimeter does not affect the area. And, of course, if the perimeter doesn't affect the area, the area would be the same.

We interpreted that E1 established *dependency between magnitudes*, providing *other arguments*. It seems that on this occasion E1 interpreted the phrase "the perimeter does not affect the area" as meaning that the area remained constant, rather than independent of the perimeter.

To conclude activity 2, he was asked to draw the necessary figures to justify his previous responses, but E1 did not express that he understood how to do so. Following the guidelines of the semi-structured interview, the interviewer offered her help. At the interviewer's insistence, E1 drew three figures that we cannot relate to his previous answers and, given his refusal to find out the perimeter and area, the interviewer decided to move on to the next activity.

Thus, in activity 3, the interviewer asked him to draw a figure with 5 "squares" of area in the grid provided, different from the figures used before (see Figure 3). E1 drew the following figure.

Figure 8

Figure of area 5, by E1

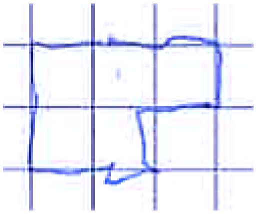


Figure 8 shows the answer that E1 provided: a figure with 5 area squares but different perimeter regarding figures A and B (see Figure 3). Subsequently, the interviewer asked him:

INT: What is the perimeter of the figure you have drawn?

E1: [Counting] Nine.

INT: That's it, write it down there, please. [E1 writes the number 9]. Does it have a different perimeter than the figures used before that had area 5?

E1: [Looking at the figures] Yes.

INT: That's it. And why do you think it has a different perimeter? Why do you think it has a smaller perimeter?

E1: Because I have counted them and they are [counts the perimeter of the figure that has drawn] one, two, three, ... and ten. My mistake! It's not that I was wrong, it's that I got the wrong answer.

INT: Okay, if you want to change anything, change it.

E1: My answer is yes because it has exactly ten and the others have more.

INT: And why do you think the others have more?

E1: Because I have counted them.

INT: Okay, okay, all right.

We interpret that, on this occasion, E1 understands that the constructed figure has the same amount of area as the given figures, but a different perimeter, and argues this by calculating the perimeters by counting the units that compose each perimeter.

Student E2

To perform activities 2.1., 2.2. and 2.3., the interviewer asked E2 to look at the given figures (see Figure 2) and then asked him "do you think that two different figures can have the same area, but different perimeter?". E2 calculated the area of the first two figures given and replied:

E2: A and B

INT: What about A and B?

E2: They have the same area, look: [referring to figure A] one, two, three, four. And [referring to figure B] one, two, three, four. And different perimeter.

INT: So, yes, it is possible. So, your answer is yes and now it says: "explain your answer".

E2: [...] Well, I can explain because I've seen it. Can I write that?

We interpret that the answer of E2 shows *independence between the measurements*, providing *examples*.

When the interviewer asked E2 if two different figures could have the same perimeter, but different area (activity 2.2), E2 tried to rely on concrete examples. The conversation between E2 and the interviewer on this occasion was as follows:

E2: No

INT: Isn't it possible?

E2: Because... it's not here, or is it?

INT: I don't know, it's what you think. What do we write there?

E2: It's possible that they might, yes.

INT: Yes, or no? I didn't hear you, sorry.

E2: That it might be possible, I imagine.

INT: Fine, you just write what you think, okay? But remember that then you must explain why.

E2: It's not here, but maybe in some [figures]... for example, the same as in some other... the fact is that there exist many, but many, many more [figures] than these. And for sure, very sure, absolutely sure, there is one that has the same perimeter.

We interpret that E2 established *independence between the magnitudes* and, finding no examples to support his idea, provided *other arguments.* The student was able to generalise from the examples given to the existence of 'many, many more figures", which allowed him to reason the independence between the magnitudes.

In activity 2.3, E2 was required to draw the necessary figures to justify his previous answers, in this case, the manifest independence (same area different perimeter).

Figure 9

Figures with the same area and different perimeter by E2

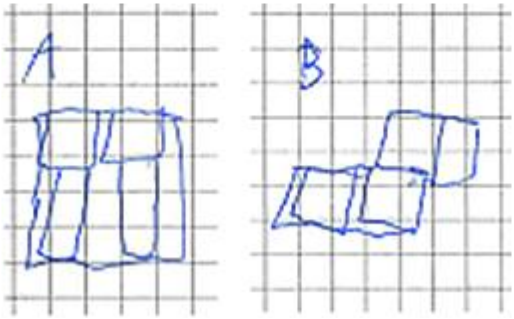


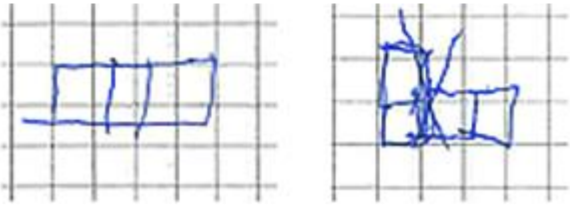
Figure 9 shows the two figures constructed by E2. In this case, the student first drew the outline of the figures and then filled each with four area squares. It should be noted that E2 did not use the squares of the grid provided as a unit of measurement of area, but instead made drawings using squares of different sizes. Through these examples, E2 again established the idea of *independence between perimeter and area*.

The interviewer then asked him to draw figures to justify his answer to activity 2.2., in which he had established the independence between magnitudes when the perimeter remains constant. E2 tried to draw two figures with the same perimeter and different area but did not find any pair of figures with these characteristics. First, he drew one of area 3 (see Figure 10, left). Then he drew another of area 3 in the form of an L, and indicated:

> *E2: Oops! I did it wrong. Because I did the same perimeter and the same area.*
>
> *INT: Can you fix it? Or do you want to make a drawing of another figure? Here you have blank pages in case you need more.*
>
> *E2: I'll do another one here [adds a square on the far right, until the figure is complete (see Figure 10, right). [Looking at his figures, discouraged] Well... Well, that's how it turned out. So, nothing ... [he abandons exercise]*

Figure 10

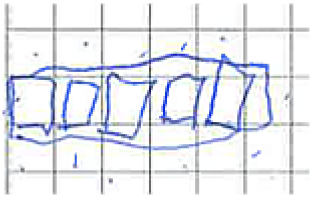
Attempted drawing of figures to justify "same perimeter different area"



To perform the next activity, the interviewer showed E2 the figures of activity 3 (see Figure 3), and asked E2 to draw a figure with 5 small squares of area that was different from these figures. E2 made the following drawing (see Figure 11):

Figure 11

Figure with 5 small area squares, by E2



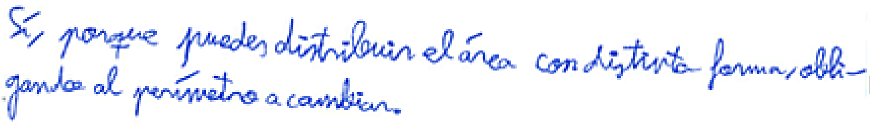
To verify that the drawn figure met the requirement of having a different perimeter to the previous ones, E2 calculated the perimeter of the figure he drew. Figure 11 shows the pen marks that E2 made when counting one square at a time. In this case, E2 seems to use the given grid as a guide, although he draws the squares separate from each other, and surrounds them with a curve to define the outline of the figure. This answer is therefore classified as *independence between perimeter and area* by means of examples.

Student E3

To perform activities 2.1., 2.2. and 2.3. the interviewer showed E3 some figures (see Figure 2) and allotted him some time to observe them. Then she asked him, “Do you think that two different figures can have the same area, but different perimeter?” Figure 12 shows E3's answer.

Figure 12

E3’s statement



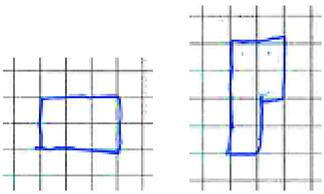
We interpret that he established *independence between perimeter and area*, and we classify the justification as *other arguments*, since the student provided an explanation based on the attributes of the figure, such as form, without alluding to examples in his argument.

When asked if two different figures can have the same perimeter and different area (activity 2.2.), E3 initially responded as follows: “No, because adding more perimeter forces us to have more.” He remained thoughtful, crossed out that answer, and wrote, “No, because completing the area forces you to add more perimeter.” In this case, the student shows a *dependency between perimeter and area*, providing *other arguments* as justification.

In the next activity, E3 was required to draw the necessary figures to justify the answers given in activities 2.1 and 2.2. To justify the independence he had established (that there are figures with the same area but different perimeter), E3 drew the following figures (see Figure 13):

Figure 13

Figures with the same area and different perimeter

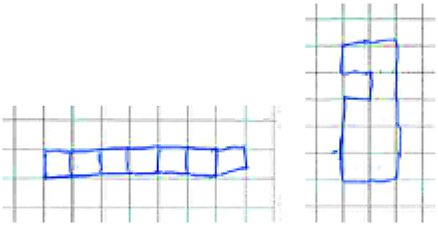


After finishing the drawing, he argued as follows: “This one has [pointing to the figure on the left] perimeter ten and area six. And this one has [pointing to the figure on the right, and counting] perimeter eleven and area six.” His answer was therefore classified as *independence between perimeter and area*, this time by way *of examples*.

The interviewer then asked the student to demonstrate his assertion about the dependency between perimeter and area when the perimeter remains constant (answer to activity 2.2.). E3 drew the following shapes (see Figure 14):

Figure 14

Figures with the same perimeter and different area



After he finished drawing the figures, it was immediately evident that E3 realised his mistake when he established a dependency between the magnitudes. The dialogue between E3 and the interviewer was as follows:

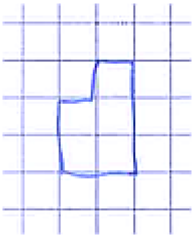
> *E3: Ah, well, no.*
>
> *INT: What’s happened?*
>
> *E3: That you can... have more area with the same perimeter. [...] Because if you change the shape of the perimeter, you can add more area.*
>
> *INT: Okay, and why?*
>
> *E3: Because here [points out figure 11, left] there is only a straight line, and with that perimeter it gives me area 7. But here it gives me area 9 and because I have changed the shape, I have perimeter 16.*
>
> *INT: Okay, you're telling me that with the same perimeter you can have a different area.*

E3: [Nods]

The interviewer then asked E3 to draw a figure with 5 area squares that was different from the figures in Figure 3 (activity 3). E3 drew the following figure (see Figure 15):

Figure 15

Area 5 figure

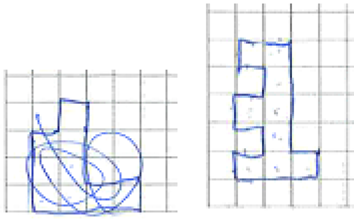


He reported that the perimeter of the figure was 10. When asked by the interviewer: "Does it have a different perimeter from the previous figures that had area 5?" E3 replied, "Yes, because I've used a different form." He did not check that the perimeters were different but expressed an intuitive idea that a different form guarantees a different perimeter, establishing a dependency between both attributes.

Finally, the interviewer then asked him to build two polygons joining 9 squares: one that had the smallest possible perimeter (activity 4.1.) and another with a perimeter as large as possible (activity 4.2.). As a minimum perimeter polygon, he drew a square on the grid whose side measured 3. When asked by the interviewer to justify that it had a minimum perimeter, E3 replied: "because it has exactly the same perimeter number as the area. Therefore, it cannot be made smaller because it would not fit." To construct the maximum perimeter figure, E3 first drew a figure of area 9 (see Figure 16, left) and after counting the sides he indicated: "of sixteen". He remained thoughtful, and argued, "I just don't know how big it can be…" Finally he drew another polygon (see Figure 16, right) arguing on this occasion: "This one is [perimeter] 20."

Figure 16

Area 9 and maximum perimeter polygons: first attempt (left) and second attempt (right)



DISCUSSION

In this section, we discuss the results obtained with previous research described in the theoretical framework. The discussion was organised with the guidance of the two research questions.

Initial idea on area and perimeter

Two students (E1 and E2) reported not knowing the concept of perimeter and needed help from the interviewer to understand it. Other investigations with students of similar ages and typical development (Wahyu, Winarti et al., 2012) also report identifying difficulties in describing this concept.

We note that, in some answers, two participants expressed that they understood the concept of perimeter but identified it as magnitude (pointing to the outline, for example, in the case of the perimeter), and not as the amount of magnitude. This may be because in the Spanish language the words “perimeter” and “area” refer both to the magnitude itself and to the result of a measurement (“calculate the area of...”). This fact, together with the fact that it is common for students with LD to show certain difficulties in understanding technical terms (Güven & Argün, 2021), the need for greater precision of language by teachers in the type of question asked is made manifest, in order not to lead to errors in their interpretation and to promote a clearer understanding of what is being asked.

Regarding intuitive ideas about the perimeter and the area, it is obvious that the three students perfectly distinguish the main characteristics of each of the magnitudes, unlike previous works such as Duoady (1988) or Silva (2009);

in fact, the three share a one-dimensional perception of the perimeter (alluding to “what surrounds an object”) and a two-dimensional nature of the area. This fact has led them not to make mistakes in identifying the perimeter and the area of specific figures and to correctly solve these tasks - a prominent error in this educational stage, described in Dickson, Brown and Gibson (1991), cited in Nortes Martínez-Artero and Nortes-Checa, (2013). In the resolution of these activities, answers based on counting the units of measurement established for each of the cases are observed, and not using formulas, which again confirms that the three students correctly understand these magnitudes and their interpretation, and proposes that this type of resolution is completely motivated by the visual-spatial capacity of this student body (according to Güven & Argün, 2018).

Area-perimeter relationship

When the students are set tasks that involve the area and the perimeter to see if they establish any kind of relationship between these magnitudes, the research leads us to conclude that all the students understand that the perimeter and the area are not related when the area remains constant, showing that there is an *independence between perimeter and area*. However, when keeping the perimeter constant, E1 and E3 establish *dependency* between these magnitudes, and only E2 maintains the idea of *independence*. As Stavy and Tirosh (1996) show, this is a very common error, which is largely due to the intuitive idea “the more of A, the more of B”. Despite this, exemplifying their responses has helped them to regain independence between the magnitudes (E3 in activity 2.3 and E2 in activity 3). Other studies (Ávila and García, 2020) show that visualising or manipulating figures that make evident the independence between magnitudes helps the students to realise it.

About the arguments provided to determine the possible relationship between the area and the perimeter in the different activities proposed: the three students predominantly use exemplification, which proposes the need to begin with a type of CSA didactic sequence for a better acquisition and understanding of these magnitudes (following Hord and Xin, 2015).

CONCLUSIONS

In this work we have addressed the problem of analysing which are the intuitive ideas associated with the perimeter and area magnitudes expressed by students with ASD, an investigation that complements others about the learning of geometric magnitudes in students with special learning needs and that opens different lines of research, focusing on students with ASD.

The case study has allowed us to better understand the type of reasoning of three primary education students with ASD and to see what are the intuitive ideas, the type of reasoning and the difficulties they have in measurement tasks, related to the concepts of area and perimeter; remarking on their correct understanding about what is the perimeter and what is the area of a flat figure and their strategies in the resolution of the measurement of these magnitudes using a predominantly counting technique. Likewise, we have detected the difficulties that these students have in activities that relate the perimeter and the area; concluding that proposing activities aimed at a greater precision of the result through exemplification helps to improve the understanding of these magnitudes and to get rid of the false idea of dependency between them.

Finally, we must mention the limitations of the study, which are fundamentally marked by the chosen methodology, a case study, which necessarily means that the results cannot be generalised.

However, thanks to the results obtained, we have a better understanding of the intuitive ideas, the type of reasoning and the difficulties that students with ASD have shown in teaching-learning tasks of the area and the perimeter, so this work sets a line of research that puts students with ASD at the centre of the learning process and that can be of great value for teachers in their day-to-day classroom duties.

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STATEMENT OF CONTRIBUTION BY THE AUTHORS

A.B.A., I.P.B. and C.L.F. conceived the idea of the research presented. C.L.F. and J.G.C. collected the data. All the authors actively participated in the development of the theory, methodology, organisation, and analysis of data, as well as in the discussion of results and conclusions.

DATA AVAILABILITY DECLARATION

The data supporting the data of this investigation will be made available by the correspondence author A.B.A., upon reasonable request.

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