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Effects of augmented and virtual reality on students with ASD

Efectos de la realidad aumentada y virtual en estudiantes con TEA

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ABSTRACT
The general objective of this research is to verify the impact of an intervention on students with Autism Spectrum Disorder (ASD) from two different perspectives, traditional and innovative with augmented reality (AR) and virtual reality (VR). It is a quantitative research study with a quasi-experimental pretest-posttest design in the same group of subjects. Two types of variables were established, the training action deployed (traditional and AR-VR approach) and the effect caused in various dimensions presented (motivation, attention, communication, autonomy and learning outcomes). The sample consisted of 23 people with ASD, with an average age of 10.52 years. It is concluded that AR and VR are useful for students with ASD, improving motivation and learning results. Comorbidity may affect learning outcomes in traditional approaches, but not in innovative ones. The appropriate and balanced use of AR and VR can maximize the benefits and minimize the possible negative effects on divided and selective attention for students with ASD.

RESUMEN
El objetivo general de esta investigación es comprobar el impacto de una intervención en alumnos con Trastorno del Espectro Autista (TEA) desde dos perspectivas diferentes, tradicional e innovadora con realidad aumentada (RA) y virtual (RV). Se trata de un estudio de investigación cuantitativo con un diseño cuasi-experimental pretest-postest en un mismo grupo de sujetos. Se establecieron dos tipos de variables, la acción formativa desplegada (enfoque tradicional y RA-RV) y el efecto causado en las distintas dimensiones presentadas (motivación, atención, comunicación, autonomía y resultados de aprendizaje). La muestra estuvo formada por 23 personas con TEA, con una edad media de 10,52 años. Se concluye que la RA y RV son útiles para estudiantes con TEA, mejorando motivación y resultados de aprendizaje. La comorbilidad puede afectar a los resultados del aprendizaje en los enfoques tradicionales, pero no en los innovadores. El uso adecuado y equilibrado de la RA y la RV puede maximizar los beneficios y minimizar los posibles efectos negativos en la atención de tipo dividida y selectiva para los alumnos con TEA.

KEYWORDS · PALABRAS CLAVES
Autism, virtual reality,Aumentaty reality, educational technology, special educational needs.
Autismo, realidad virtual, realidad aumentada, tecnología educativa, necesidades educativas especiales.

1. Introduction

Autism Spectrum Disorder (ASD) as a set of neurodevelopmental disorders with a multifactorial character (APA, 2013) due to an alteration or disorder in people's social skills (Raptopoulou et al., 2021). Similarly, people with this disorder demonstrate problems in communication skills, as well as repetitive and stereotyped behaviours (Martínez-González et al., 2022). Taking as a reference the latest update (11th) of the International Classification of Diseases (ICD-11), ASD begins to manifest itself during the development of individuals, that is, in childhood.

In the same way, people with ASD may show difficulties in executive functioning, as well as presenting other affected symptomatological conditions such as sensory and perceptual behaviour (López & Ferrando, 2023). In turn, ASD can lead to difficulties in task planning, language problems (Adams & Gaile, 2020) and even impairments in writing (Mohamad et al., 2022). They may also report attention problems, depression, anxiety, aggression, defiant behaviour, restricted interests and emotional problems, among the most significant (Fredick et al., 2022). These particularities may be exacerbated if the person has low cognitive levels (Kuenzel et al., 2021).

Likewise, ASD may be directly related to hearing difficulties, denoting atypical responses to environmental sounds (Alho et al., 2021). Conversely, individuals may exhibit superior music processing skills as compared to individuals with typical development (Bacon et al., 2019). Furthermore, individuals with ASD may exhibit abnormal perception as regards touch (Gómez-Aguirre et al., 2023). These individuals may also exhibit motor problems which can last throughout their lives, leading to complications, both in their autonomy and in everyday life activities (Van Damme et al., 2022). Other difficulties along these lines include the visual processing of people's faces as a result of hypoactivation of the fusiform area of the face (Tang, 2022), which can likewise affect colour processing (Mohamad et al., 2022).

Furthermore, ASD may present comorbidity with other pathologies including attention deficit/hyperactivity disorder, severe conduct disorder, depression and anxiety related disorders, obsessive-compulsive disorder, sensory integration disorder and even intellectual disability (Alcalá and Ochoa, 2022; Fernández-Menéndez et al., 2022). Clinically, the diagnosis of ASD focuses on the phenotype of individuals, as no laboratory tests are reported for this purpose. In this regard, ASD is not treated pharmacologically, but rather from a therapeutic perspective (Domínguez-Lucio et al., 2022).

Statistically, ASD worldwide can be estimated at 1.5% of the total population (Fusar-Poli et al., 2020). In Europe, a prevalence estimate of 1 per 100 persons is found, and in Spain ~~in~~ specifically, an exact figure is not known. Only a considerable increase in the number of cases is reported. Its justification lies in the application of tools with greater validity and reliability, as well as in the training and experience of the professionals involved (Confederación de Autismo España, 2019).

High profile experts in the area postulate that educational practices for people with ASD pose an extra difficulty given the multifactorial nature of this disorder, so that each proposal must be tailored, to a large extent, to the singularities of the students in question (Macmillan et al., 2021). In this respect, special attention must be paid to the needs of the students, since the range can vary from a competence deficit (Carmona-Serrano et al., 2021), to non-compliance with guidelines for carrying out training practices or not paying the required attention to instructions or explanations (Latorre-Cosculluela et al., 2022). Another aspect to

be taken into account is the communicative level between the various agents and their combinations (student-student; student-teacher), which poses a challenge due to the alterations that may arise in communication. It is therefore recommended that all training practice should be geared towards the promotion of interpersonal communication. This will contribute to improving the social component that is affected in people with ASD (Chiva-Bartoll et al., 2021).

Likewise, it is recommended to start working early on all the difficulties and deficiencies which people with ASD have (Hadders-Algra, 2021). This is based on the premise of observing the behaviour or actions of a role model as the most effective method (Rahman et al., 2022). In this regard, any pattern to emulate must be based on the principles of autonomy in daily life activities (Laverdure and Beisbier, 2021); likewise, interdisciplinary work should be encouraged, taking the area of science as the axis, with the purpose of helping these individuals to understand the reasons for things. This aspect will help the students to understand what is happening around them (Jackson and Hanline, 2020). It is likewise advisable to work on the regulation of emotions according to each situation, time and place, to positively influence the social component and remedy problems derived from bad behaviour (White et al., 2021).

At an academic level, in general, students with ASD tend to perform poorly, due to the difficulties encountered in the teaching and learning process. Conversely, no studies have been reported that support the opposite, that is, high academic performance, which may be an interesting field of study to explore (Spaniol et al., 2021). An aspect which is of significant relevance in all this is the training of professionals who design and carry out interventions, since poor practice can be counterproductive on a social level, further isolating the person with ASD (Gomez-Mari et al., 2021). Experts advocate specialised in-service training, as initial training is scarce. The purpose of this is to carry out effective actions that have a positive impact on their quality of life and near future, achieving the necessary autonomy to function effectively in society. In this regard, intervention must be focused on the pi~~llars~~ foundations of educational inclusion (Saade et al., 2021).

Notwithstanding all these recommendations, the professionals who carry out the intervention should not work in isolation, but rather in collaboration with each other and with the families. Coordinated work at home can be very beneficial in reducing certain behaviours and improving their mental health. This will undoubtedly have a positive impact on learning tasks (Sreckovic et al., 2021).

In the school environment, the prevalence is 1 in 4 students who have specific educational support needs is ASD (*Confederación de Autismo de España, 2020*). In the primary education stage, the figure rises to 52% of the reported needs. Conversely, this decreases in secondary education, due to school drop-outs, bullying or change of educational modality, among the most highlighted reasons. In higher education this figure increases, with the number of people with ASD pursuing university studies increasing (Viezel et al., 2020).

1.1. Augmented and Virtual Reality in students with ASD

Technological tools provide support as a methodological resource to address diversity in the teaching-learning process. Focusing on emerging technologies such as augmented reality (AR) and virtual reality (VR), these have been used to improve the difficulties of

students with ASD. There is a wide range of AR and VR resources that are suitable for educational purposes and are integrated into mobile applications (Gallardo-Montes et al., 2021). It all depends on the creativity of the teacher to adapt the application to the content that he/she wishes to work on at that moment (Tunjo-Guerrero and Yangali, 2021). There is also the possibility that teachers themselves can generate their own environments with both technologies, but this is already influenced by their level of digital competence and good practices (Moreno-Guerrero et al., 2021).

AR and VR allow teachers to perform digital competences integrated into the Digital Competence Reference Framework for Teachers (DCRFT), specifically area 2 "digital content" (Resolution of 4 May 2022) as teachers create their own digital resources and become prosumers. An example of this is the production of specific objects such as video and audio clips, creating specific materials in 3D visualisation, even specific software for programming the interaction of digital reality with physical reality and the combination of different objects (Cabero et al., 2017).

AR contributes to promoting positive collaborative attitudes, enhancing social interaction, personal growth and users' competences in handling this type of tools (Sdravopoulou et al., 2021). AR has been used through mobile devices, such as Smartphones or tablets, which have made it possible to launch the content collected in the application for corresponding visualisation and user-machine interaction (Wedyan et al., 2021). Nevertheless, students consider the use of AR from a dual perspective: on the one hand, it has high levels of satisfaction and positive attitudes, and on the other, it has a series of limitations and obstacles (Barroso et al., 2019).

Focusing AR on attention to diversity, this resource has facilitated work on reasoning, decision-making and problem-solving through the interactive activities launched on the electronic device. All of this has a positive impact on the autonomy of students with ASD (Baragash et al., 2020). Another possibility that AR presents for students with ASD is the ability of this technology to promote the social aspect, where students can interact with avatars or digital characters, influencing the development of communication (Almurashi et al., 2022). Likewise, this technology has facilitated cognitive work through highly sensorially stimulating digital environments (Danaei et al., 2020).

Likewise, VR has also achieved great benefits in addressing the difficulties encountered in students with ASD. This immersive computer-generated technology has led to increased motivation by generating unique learning experiences (Zhang et al., 2022). Although VR can lead to increased stress and anxiety due to its high stimulation, experts recommend the use of screens that replace glasses, in order to generate a more controlled and less exciting experience (Alcañiz et al., 2019).

In turn, VR allows the learning environment to be adapted to the needs of the ~~learner~~ student. This contributes to the regulation of the aforementioned stress and anxiety, by generating a safe and pleasant virtual environment for the subject (Johnston et al., 2020). Like AR, VR practices promote, as the scientific literature indicates, the autonomy and attention of students with ASD (Amat et al., 2021).

Furthermore, educational practices supported by these technologies promote active learning, as students control the learning process by deciding when they require additional information and by combining the real and the virtual. This facilitates the development of a constructivist teaching-learning methodology, where students are active learners who make

their own discoveries by relating the information presented in different ways and reaching their own conclusions (Barroso et al., 2018).

1.2. Justification and objectives

One of the principles of education is inclusion. Furthermore, the study of innovative methodologies integrating digital tools provides the scientific and educational community with evidence on the effectiveness of AR and VR in inclusive education in general, and students with ASD in particular. This allows for the identification of best practices, the development of effective interventions and the promotion of informed adoption of these technologies in inclusive educational environments.

For this reason, the overall objective of this research focuses on ascertaining the scope of an intervention for students with ASD from two different perspectives (traditional and innovative). From this overall objective, the following specific objectives will serve as guidelines to this study:

To understand the impact of each educational programme according to the training methodology utilised in the motivation, attention, communication, autonomy and learning outcomes of the students.

To analyse whether the effects generated in each of the dimensions vary according to the presence or absence of associated comorbidity.

In order to clarify these specific objectives and undertake the research, the following research questions (RQ) were established:

- RQ1: Does the training approach modality influence the motivation of students with ASD?
- RQ2: Does the training approach modality influence the attention of students with ASD?
- RQ3: Does the training approach modality influence the communication of students with ASD?
- RQ4: Does the training approach modality influence the autonomy of students with ASD?
- RQ5: Does the training approach modality influence the learning outcomes achieved by students with ASD?
- RQ6: Does the presence of comorbidity associated with ASD influence the assessments obtained in the various dimensions studied?

2. Methodology

2.1. Research design and data analysis

This study was undertaken using a quantitative research methodology. Specifically, a quasi-experimental pretest-posttest design was undertaken on the same group of subjects. For the utilisation of the research, the guidelines of experts in this type of study were taken into account (Hernández et al., 2014).

Two types of variables have been established in the research. On the one hand, the training action utilised (traditional approach and AR-VR), as an independent variable and, on the other, the effect caused in the various dimensions presented (motivation, attention, communication, autonomy and learning outcomes), as a dependent variable, of a numerical (quantitative) type.

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In this study, an intervention has been applied in which aspects such as attention, communication, fine and gross motor skills, as well as eye-hand coordination (as didactic content) have been worked on through the application of the independent variables in the subjects in order to ascertain how it influences the dependent variables, as well as the incidence of comorbidity in all of this.

Data analysis was undertaken using the SPSS programme version 25. This has enabled the performance of statistics such as the mean (M) and standard deviation (SD). Skewness and kurtosis tests were likewise undertaken to determine the direction of the sample distribution. Student's t-test was used to compare pre-post means. Cohen's d and the biserial correlation (rxy) were used to determine the size of the effect. Furthermore, Pearson's chi-square test ($\chi 2$) was used to ascertain the degree of association between the dimensions and the presence of comorbidity, together with Cramer's V (V) and the contingency coefficient (Cont). Therefore, in this study, values of $p < .05$ were stipulated as statistically significant differences.

2.2. Sample

The sample comprised of 23 Spanish students with ASD. In terms of gender, 73.9% were boys and the rest girls, with a mean age of 10.52 years (SD=4.26). As regards comorbidity, 21.7% of the participants had no comorbidity, 60.9% had a single comorbidity and 17.4% had two or more.

The sampling technique used for the selection of these participants was premediated, due to the ease of access to the sample of subjects from such an institution. As sample inclusion criteria, it was established that the participants in this study had to accept informed

consent from their families or legal representatives. In this regard, no exclusion criteria were established in order to attain the maximum sample size.

2.3. Instrument

After analysing the literature as regards the matter in question, instruments based on observation and recording by professionals who intervene with students with ASD have been reported. In this regard, one of the instruments that is most suitable for the characteristics of this research is the instrument developed by Lorenzo et al. (2019). This instrument has served as the basis for the design of an ad hoc tool, enables the compilation of the necessary data to respond to the stated objectives.

The designed tool is composed of 25 items, structured in the dimensions of motivation, attention, communication, autonomy and learning outcomes. In addition, the questionnaire has several items to collect socio-demographic data. The type of assessment of the tool is a Likert scale with 4 levels (1 is the most negative value and 4 the most positive).

In order to validate this instrument, an expert judgement was undertaken in which four specialists in the field of ICT and inclusive education provided their assessment and feedback on the designed tool. The validation procedure consisted of several stages: 1-Contacting the experts in the field; 2-Sending the questionnaire telematically; 3-Reception of the assessments and proposals for improvement (mainly focused on amending the wording of certain items to attain greater objectivity and reduce possible biases); 4-Making the suggested changes; 5-Sending the questionnaire again for final review; 6-Confirmation of the validity of the tool.

Finally, a valid instrument was obtained for the purposes of the compilation of the necessary data to enable the study to continue.

2.4. Process

For a relevant research process, this study was undertaken in various stages. First, the research proposal was submitted to the management of a Spanish Autism Association. Then, once the necessary authorisation was obtained, a consent model was prepared to inform the children's families as regards the research objectives, with the purpose of granting their approval to participate in the different actions that the study entailed. Next, the sample of participants derived from the informed consents favourably obtained was created. Next, the designed interventions were performed. These consisted of the implementation of five sessions using, first, a traditional training approach and, two weeks later, another five innovative sessions using AR and VR technology were undertaken. Afterwards, the data were collected through the designed questionnaire taking into account the observation of the multidisciplinary team (occupational therapist, psychologist, speech therapist and special education teacher) set up for this study. Then, a triangulation of the data performed for the purposes of obtaining maximum possible objectivity and avoid any bias in the data collection stage. This was undertaken by obtaining the mean scores for each item of the questionnaire recorded by the various professionals. Finally, a statistical analysis was performed to define the conclusions and ascertain the scope of the stated objectives and to answer the research questions.

3. Analysis and results

In the descriptive analysis undertaken, higher measurements are shown in the post-tests than in the pre-tests in all the dimensions, except in the attention dimension, where it is slightly higher in the pre-test measurements. As for the distribution of the sample, this is considered normal, given the values obtained for skewness and kurtosis. There is no dispersion of response according to the standard deviation values. The kurtosis is variable, with leptokurtic, mesokurtic and platykurtic kurtosis (Table 1).

The comparison of means shows that all dimensions are higher in the post-test measures than in the pre-test measures, except in the attention dimension, where it is slightly higher in the pre-test measures. In the latter, the dimension with the highest mean score is attention, while the dimension with the lowest mean score is motivation. In contrast, in the post-test measures, the dimension with the highest mean score is motivation, while the dimension with the lowest mean score is attention.

Table 1

Descriptive results obtained by dimensions

	Parameters							
Dimensions	**Pre-test**				**Post-test**			
	M	**SD**	**Asymmetry**	**Kurtosis**	**M**	**D**	**Asymmetry**	**Kurtosis**
Motivation	2.07	.491	-.317	-.218	3.46	.694	-1.01	-.576
Attention	2.75	.321	.089	.689	2.65	.507	.249	-.991
Communication	2.53	.641	-.475	-.638	3.27	.708	-.810	-.369
Autonomy	2.13	.487	-.659	-.040	3.00	.711	-1.246	1.502
Learning outcomes	2.16	.325	1.121	.723	3.38	.580	-1.050	.525

The Student's t-statistic indicates that there are statistically significant differences in all dimensions of the study in favour of the innovative methods, except for the attention dimension, where no significant relationship is observed. The effect size is relatively low. In the biserial correlation, a medium-high relationship is observed in the dimensions of motivation, communication, autonomy and learning outcomes (table 2).

Table 2

Student's t test, Cohen's d and biserial correlation analysis

Dimensions	μ(X1-X2)	$t_{n1+n2-2}$	gl	*d*	r_{xy}	*p*-value
Motivation	-1.39(2.07-3.46)	-7.955	22	-.035	.763**	.000
Attention	.101(2.75-2.65)	.718	22	.047	-.121	.247
Communication	-.739(2.53-3.27)	-3.804	22	-.023	.488**	.000
Autonomy	-.869(2.13-3.00)	-4.712	22	-.037	.589**	.000
Learning outcomes	-1.21(2.16-3.38)	-8.555	22	-.084	.798**	.000

Note: *Significant correlation p< .001

The relationship established between the presence of comorbidity and the study dimensions established after the application of a traditional teaching method shows that there is no correlation with any of the dimensions analysed, except with learning outcomes, where there is a correlation. In this case, the fact of having a disability associated with ASD affects the learning outcomes obtained, which, as can be seen in the table of descriptive results, yield low values. In this correlation, a medium-high strength of association is observed (Table 3).

Table 3

Correlation between comorbidity and dimensions of study with traditional approach

Dimensions	X^2(gl)	*p*-value	Cont	V
Motivation	15.372(12)	.222	.633	.578
Attention	4.771(8)	.782	.414	.322
Communication	17.045(14)	.254	.652	.609
Autonomy	10.679(14)	.711	.563	.482
Learning outcomes	25.300(12)	.013	.724	.742

In contrast, the relationship established between the presence of comorbidity associated with ASD and the study dimensions after the application of an innovative teaching method shows no correlation. In this case, the existence of comorbidity does not influence any of the dimensions (Table 4).

Table 4

Correlation between comorbidity and study dimensions with innovative approach

Dimensions	X^2(gl)	*p*-value	Cont	V
Motivation	14.862(10)	.137	.627	.568
Attention	12.945(10)	.227	.600	.530
Communication	10.956(14)	.689	.568	.488
Autonomy	18.565(16)	.292	.668	.898
Learning outcomes	19.533(18)	.360	.678	.652

4. Discussion

The inclusion of ICT in the field of education has enabled a number of potentialities to be harnessed to enhance students' learning (Krassadaki et al., 2022). In particular, AR and VR have proven to be very useful tools for improving teaching and learning, especially for people with ASD (Wedyan et al., 2021). These technologies can help improve the motivation, attention and autonomy of students with ASD by creating more immersive and personalised learning environments (Amat et al., 2021; Baragash et al., 2020; Danaei et al., 2020; Zhang et al., 2022). Moreover, these can likewise facilitate communication and social interaction for these students, who often have difficulties in these areas, as has already been verified in previous studies (Almurashi et al., 2022).

In this paper, the findings suggest a possible effectiveness of the implementation of AR and VR in interventions intended for students with ASD. A number of potential advantages are observed, including improving the understanding of the information presented in reality for students, allowing the observation of objects from different perspectives chosen by users or enriching the study materials provided to students according to the study by Cabero et al. (2017). The authors agree with Barroso et al. 2018 in considering AR and VR an interesting technology to be integrated as a methodological resource due to the existing relationship between motivation and the learning process positively influencing student performance. These results are in line with previous research, which has also identified indications that these technologies can be valuable in improving the aforementioned socio-educational dimensions (Almurashi et al., 2022; Amat et al., 2021; Baragash et al., 2020; Danaei et al., 2020; Zhang et al., 2022).

Nevertheless, an aspect of particular relevance is identified in the attention dimension, wherein the technology used has not led to improvements in this regard. This may be due to a number of factors, such as the lack of adaptation of the technology to the individual needs of each student or the lack of adequate design of activities and interfaces (Johnston et al., 2020; Tunjo-Guerrero and Yangali, 2021). In this regard, other studies have identified that attention can be improved with the use of these technologies (Amat et al., 2021), which is why it is important to bear in mind that a careful analysis of the designs and interfaces is necessary to ensure effective adaptation to the needs of each student (Gallardo-Montes et al., 2021). Furthermore, it is important to bear in mind that each student is unique and may respond differently to the use of these technologies, which is why it is important to perform an individualised assessment to determine whether t~~hey~~ these are suitable for each particular case (López-Belmonte et al., 2022).

Insofar as comorbidity of ASD with other pathologies is concerned, the literature reflects that its existence can affect the educational development of the student (Fernández-Menéndez et al., 2022). Conversely, in this study it was identified that it only affects the learning outcomes that have been worked on from a traditional perspective.

5. Conclusions

In conclusion, the findings of this study highlight the effectiveness of AR and VR as technological resources in teaching students with ASD. Specifically, the development of training proposals through these technologies has led to improvements in motivation (RQ1), communication (RQ3), autonomy (RQ4) and academic performance (RQ5) according to the

biserial correlation, in contrast to traditional approaches. Nevertheless, the attention variable (RQ2) does not show significant values when both traditional and innovative approaches have been utilised. For this reason, it is crucial to consider that, although these technologies may be attractive and offer numerous stimuli, these may also hinder selective and divided attention. Therefore, it is critical to employ AR and VR in a balanced and appropriate manner to maximise their benefits and minimise possible negative effects.

In relation to the presence of comorbidity associated with ASD (RQ6), the results indicate that, under a traditional intervention approach, the presence of additional disorders in the student negatively affects learning outcomes as can be seen in Table 3. Nevertheless, for the other dimensions analysed, both in the traditional and innovative approaches, no significant differences are observed. This evinces that a student with ASD and comorbidity with another disorder, the learning outcomes are negatively affected when using a traditional approach as opposed to when using an innovative approach, with higher values. This fact thereby underpins the theoretical basis submitted in this paper on the promotion of innovative practices in interventions with people with ASD.

This study has experienced several limitations. The main limitation was the size of the sample due to the type of population that participated in the research. On the other hand, the sociodemographic characteristics of the students were diverse. The subjects presented different ages and singularities that did not allow for grouping., And on the other, there are the designed activities, which may represent a limitation in this regard, given the fact that the results obtained herein are conditioned by such training actions. In this regard, the design and development of other proposals may have entirely different effects. Likewise, the fact of first carrying out a traditional approach may have had a certain influence on the assessments attained in the innovative approach, given the fact that it entailed the same subject and the same contents. Finally, another limitation is reported in the team of professionals who participated in the study. These professionals have been involved in the various stages of the study (design, implementation and data collection), so that a change of professional may result in a different perception of reality.

Therefore, based on the aforementioned limitations, as future lines of study it is intended to increase the sample of participants, for the purposes of validation of the proposals developed and generalise the results obtained. To this end, we shall be able to rely on the collaboration of diverse associations or centres which integrate people with ASD. Furthermore, other training proposals shall be designed using AR and VR and other educational technologies such as robotics and artificial intelligence, which are currently booming in the field of education, shall be implemented. Moreover, two working groups shall be set up. One working group shall be in charge of the design and intervention stage, and the other of the data collection stage. This is to reduce any bias derived from the subjectivity of the professionals.

The prospective of this research is both theoretical and practical. In theoretical terms, this work has led to an increase in the literature as regards ASD, particularly in relation to the application of emerging technology such as AR and VR for the utilisation of innovative learning practices. Likewise, the theoretical bases that affirm how technology benefits various psychoeducational dimensions during the development of training practices, irrespective of the presence or not of comorbidity, have been reflected and strengthened. On a practical level, the results have highlighted the need to improve the design of digital applications to avoid the reception, by the student, of a great deal of sensory stimulation that

causes an undesired effect, such as the appearance of possible distractions or lack of attention which results in the participant not attaining the proposed objectives for said activity.

Authors' Contribution

Conceptualization, **J. L.-B.**, **P.D.-T.** and **J.-A.M.-M**; data curation, **J. L.-B.**, **P.D-T.** and **J.-A.M.-M.**; formal analysis, **J.L.-B.** and. **A.-J.M.-G.**; funding acquisition, **J. L.-B.** and **J.-A.M.-M.**; investigation, **J.L.-B.** and. **A.-J.M.-G.**; methodology, **J.L.-B.**; project administration, **J. L.-B.**, **A.-J.M.-G.** and **J.-A.M.-M.**; resources, **J. L.-B.** and **P.D.-T.**; software, **A.-J.M.-G.**; supervision, **J. L.-B.**, **P.D.-T.**; **A.-J.M.-G.** and **J.-A.M.-M.**; validation, **A.-J.M.-G.**; visualization, **J. L.-B.**, **P.D.-T.**, **A.-J.M.-G.** and **J.-A.M.-M.**; writing—original draft preparation, **J. L.-B.**, **P.D.-T.**, **A.-J.M.-G.** and **J.-A.M.-M.**; writing—review and editing, **J. L.-B.** and **P.D.-T.**

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