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## COREAT: Developing a Mobile Application to Assess the Severity of Repetitive Behavior in Autism

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**Abstract:** Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterised by difficulties in communication and repetitive behaviors. The early detection of ASD is a clinical priority in education centres and medical services. COREAT is a computer adaptation of the Repetitive Behavior Scale-Revised (RBS-R) which has been designed to facilitate the diagnosis of individuals with ASD and intellectual disability. This article describes the development, an initial evaluation of the feasibility and the preliminary outcomes of COREAT. The development of COREAT consists of two phases. Phase 1: Performing a prior analysis of the psychometric properties of the RBS-R scale. Phase 2: Developing the mobile application (pilot tests, testing real cases  $n = 11$ , and final feedback). Descriptive data of the pilot study shows that 91.31% of participants indicate that COREAT is very accessible and intuitive. COREAT proves to be a useful diagnostic resource for professionals and families. Cross-cultural differences must be analysed.

**Keywords:** Autism spectrum disorder, COREAT, mobile applications in subject areas, RBS-R, repetitive behaviour.

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### Introduction

The prevalence of parent-reported autism spectrum disorder (hereinafter, ASD) is 1 in 40 (2.5%) among children aged 3–17 years (Kogan et al., 2018). In the same line, a recent study indicates that the prevalence of ASD is 18.5% per 1,000 in 8-year-old children, and that ASD is 4.3% more frequent in boys (Maenner et al., 2020). ASD is characterised by the presence of two symptoms: deficits in social interactions, and restricted and repetitive behaviours (hereinafter, RRBs) (American Psychiatric Association or APA, 2013). RRBs are activities or interests that occur regularly and interfere with daily performance. These RRBs manifest in the form of compulsive behaviours, stereotypies, circumscribed interests and behavioural problems (Bodfish et al., 2000). Furthermore, there is a connection between the severity of repetitive behaviours and social adaptation to the educational center (e.g., special education school, typical public-school classroom with support, part-time typical classroom, part-time special needs classroom, specialised public autism class with some form of inclusion or mainstreaming, etc.) in individuals with ASD. Specifically, self-injurious and stereotypic behaviours require a higher level of support and supervision in the educational center (Martínez-González & Piqueras, 2019a).

From the family, educational and clinical fields, there is great concern about the difficulties to manage the emotions in individuals with ASD (e.g., Vogan et al., 2018). Scientific literature has tried to figure out the factors that affect executive dysfunction, and therefore, the lack of emotional self-control in individuals with ASD. High levels of severity of RRBs (e.g., self-injury) are associated with high levels of anxiety and emotional distress (e.g., Lydon et al., 2015; Martínez-González et al., 2021; Uljarevic, & Hamilton, 2013; Yang et al., 2015). Thus, RRBs are main symptoms in ASD which can have the task of reducing levels of anxiety (Gabriels et al., 2013).

The importance of the hypothesis about the microbiota-gut-brain axis in ASD has been highlighted recently. This hypothesis says that there is a relationship between dysbiosis in the gut microbiota, gastrointestinal symptoms and RRBs in ASD (e.g., Andreo-Martínez et al., 2019, 2020, 2022; Martínez-González & Andreo-Martínez, 2019). Therefore, the severity of repetitive behaviour might be an indicator of gastrointestinal problems and not adapting to school

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(Martínez-González, & López-Gil, 2019). In this sense, studies indicate that children with ASD who have gastrointestinal symptoms present significantly higher rates of anxiety, sensory hyper-reactivity and chronic abdominal pain (Mazurek et al., 2013, 2014). Therefore, these results suggest that anxiety, sensory hyper-reactivity, gastrointestinal symptoms and abdominal pain are possibly interrelated phenomena and may have common underlying mechanisms.

The *Repetitive Behavior Scale-Revised* (RBS-R; Bodfish et al., 2000) is the most commonly used scale to assess RRBs in ASD. The RBS-R assesses repetitive behaviours through 43 items grouped into six different dimensions of repetitive behaviour in individuals with ASD and/or intellectual disability (ID). These factors are stereotypic, self-injurious, compulsive, ritualistic, sameness, and restrictive behaviours. The items are classified on a 4-point Likert scale from 0, which refers to a repetitive behaviour that does not occur, to 3, indicating a very serious repetitive behaviour. The assessment of repetitive behaviour is based on observations and interactions during the last month by a relative, caregiver or professional who knows the person well. The RBS-R has excellent psychometric properties among individuals with ASD, with its six-factor structure, adequate reliability and concurrent-divergent validity in different countries (e.g., Esbensen et al., 2009; Fulceri et al., 2016; Georgiades et al., 2010; Inada et al., 2012, 2015; Kästel et al., 2021; Lam & Aman, 2007; Martínez-González & Piqueras, 2018, 2019b; Mirinda et al., 2010; Rojahn et al., 2013). Furthermore, each dimension represents a specific and separate measure which can be used for RRBs (Sturm et al., 2022).

However, there is no mobile application in the scientific literature that enables measuring the severity of RRBs in individuals with ASD and/or ID. An online adaptation or mobile application of the RBS-R would help with its transfer to society. On the one hand, families would benefit from having up-to-date information on the severity of their children's repetitive behaviour. On the other hand, it would be a much-needed technological resource in the fields of medicine, psychology and education.

### *Objective*

The aim is to describe the development of the COREAT in Spain. A mobile application that makes it possible to measure the severity of RRBs using the RBS-R test (<https://web.ua.es/es/ginta/app-coreat.html>).

## **Methodology**

### *Design and development*

Overall goals: The overall goal is to describe the development of a mobile application which enables the assessment of RRBs in individuals with ASD and/or ID. The use of the COREAT mobile application is described and examined in this article.

Development team: The development team included a multidisciplinary team (psychologists and software developers) as recommended by Baranowski et al. (2013). The overall development partnership was between the GINTA research group at the University of Alicante (Spain) and CubeCut Software (Alicante, Spain). The collaborative development team included members with expertise in behavioural science, psychometry, app design, programming and graphic design. The team worked interactively throughout the development and dissemination phase of the mobile application.

### *Data information*

COREAT has been designed and programmed using Xanmarin Forms with C # language (Hermes, 2015). COREAT does not allow storing numeric data within a database, so there is no repository with data stored on the Internet. Similarly, COREAT does not allow the inclusion of personal data (e.g., surnames, name, etc.) or an email address where to receive more information about the results. The person performing the test immediately obtains the final results thanks to a computer algorithm. However, the person cannot store or save them on their mobile phone. The only way to save the final information on the results is by taking a screenshot of the tables and brief feedback. In this way, total anonymity of the assessed person is achieved, following the guidelines of the Spanish data protection law (Orgánica, 2018).

### *Procedure*

Rounds of developmental research were conducted according to the recommendations by Baranowski et al. (2013). For example: identifying information needed to develop the mobile application, usability testing, and pilot testing to examine feasibility and acceptability. See Figure 1 for the conceptual framework for the development of COREAT.

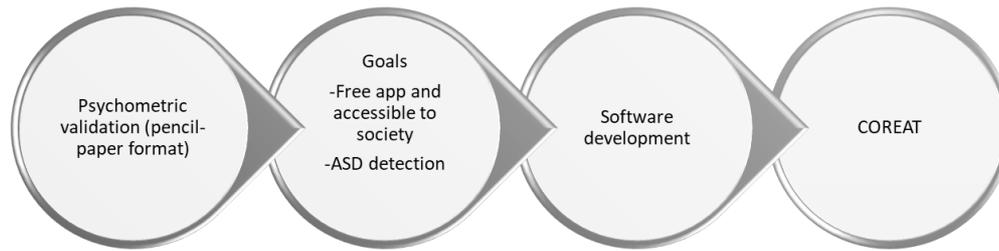


Figure 1. Conceptual framework for development of COREAT.

Information needed to develop the COREAT mobile application: The COREAT app contains the RBS-R test which follows DSM-5 diagnostic criteria (APA, 2013) to assess the existence and severity of RRBs in individuals with ASD. The final project goal was to have a free mobile application that could be easily accessible for professionals (psychologists, psychiatrists, pediatricians, teachers, etc.) and families.

Several development team meetings were held over five months (between April and September 2019) to: 1) Ensure the team is familiar with the RBS-R scale, 2) perform a previous psychometric analysis and obtain standard scores of the RBS-R (Martínez-González & Piqueras, 2019b), 3) develop the software and include the standard scores within the mobile application, 4) define the colour, type and size of the font, 5) design the logo, 6) perform the graphic design of the mobile application, 7) include the standard scores of the RBS-R within the mobile application, 8) write short report templates for people after using COREAT, 9) conduct final psychometric adjustments and 10) perform final design adjustments.

The test execution time with the COREAT mobile application is approximately 10 minutes. The COREAT user can choose one of the four diagnostic profiles to assess. Specifically: 1) Suspected ASD; 2) Person with ASD without ID; 3) Person with ASD and ID; 4) Person with ID. In addition, the variables of age and sex can be provided before beginning the test.

The items of the RBS-R are part of the following dimensions: stereotypic, self-injurious, compulsive, ritualistic, sameness, and restrictive behaviors. The online version of the test is identical to the Spanish adapted version. Thus, instructions and items of the RBS-R have not been modified within COREAT. Therefore, the development of COREAT is based on the autism theoretical model for the RRBs (Bodfish et al., 2000) and the criteria of severity of repetitive behavior according to DSM-5 (APA, 2013).

Alpha and beta testing of COREAT: alpha testing was conducted to examine prototypes of COREAT. Four versions of the mobile application were examined throughout the early development process. Multiple versions were tested by the developers, families that have children with ASD (n=3), professionals (n=8), and other colleagues, all of which provided feedback afterwards. All the recommendations on colour, font size, test response mode and style of the tables and graphs were taken into account for the final version of COREAT. Beta testing opportunities provided information on the acceptability and feasibility of the mobile application. Psychometric data were reviewed after conducting the test. Furthermore, a feedback message was incorporated into the test, which users see after using COREAT. The message is designed for profile option "Suspected ASD". It provides brief feedback or a report according to the psychometric results found. General feedback in the alpha and beta testing activities resulted in multiple improvements to the app, such as increased font size for words and modifications to the colours, logo, design and size of figures or graphs, as well as a psychometric review, and brief feedback or a report for the user in the "Suspected ASD" profile option.

COREAT description after alpha / beta testing and references: COREAT can be used by families and professionals (physicians, psychologist, teachers, etc.) on a mobile phone.

The home page includes information about the research, the mobile application developer and the option to start the test (see Figure 2).



Note. Investigación= Research; Empezar= Start; Desarrollador= Developer  
 Figure 2. Home page

The research section includes information on the following: 1) Description of the app; 2) An “important note” (stressing that COREAT does not allow the inclusion of personal data, that data is anonymous and there is no possibility of storing said data); 3) Ethical information; 4) Project director; 5) References (see Figure 3).



Note. Volver= return  
 Figure 3. Research section

The variables of age, sex and diagnostic profile (Suspected ASD, ASD without ID, ASD with ID, and ID) are included in the “Start” section (see Figure 4). Furthermore, information on the protection of personal data is included according to Spanish law (Orgánica, 2018).

*Note.* Edad=Age; Sexo= Sex; TEA= ASD; No se si puede tener TEA= suspected ASD profile; Tiene TEA sin discapacidad intelectual= ASD without intellectual disability; Tiene TEA con discapacidad intelectual= ASD with an intellectual disability; Tiene solamente discapacidad intelectual= only an intellectual disability; Empezar= Start

Figure 4. Start section

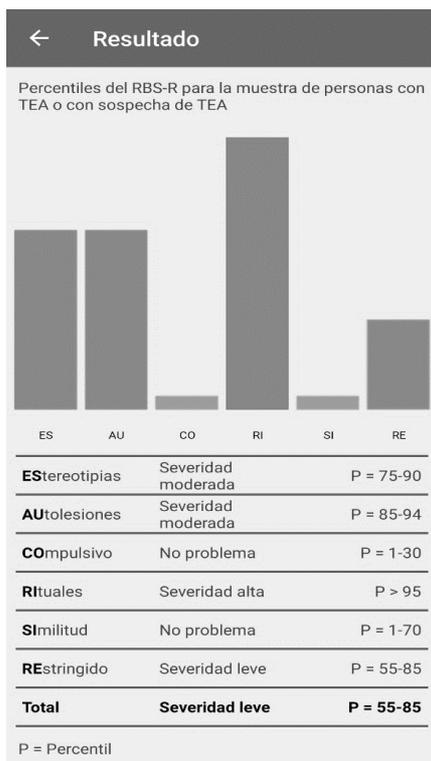
Test start section: The original instructions and RBS-R items are included herein (see Figure 5).

← Preguntas	← Valoración
<b>Subescala de Comportamiento Restringido</b>	<b>TODO EL CUERPO (se mece, se balancea)</b>
(DEFINICIÓN: gama limitada de atención, interés o actividad)	Al decidir la puntuación para cada ítem, tenga en cuenta lo siguiente: (a) la frecuencia con que ocurre el comportamiento (por ejemplo, semanalmente frente a cada hora), (b) lo difícil que resulta interrumpir la conducta (por ejemplo, se puede redirigir fácilmente o se angustia si se le interrumpe) y (c) hasta qué punto el comportamiento interfiere con la realización de otras actividades en curso (por ejemplo, es fácil de ignorar o es muy perturbador).
Por favor, puntúe el comportamiento de esta persona leyendo cada uno de los ítems de la lista y luego escoja la puntuación que mejor describa en qué medida el ítem es un problema para la persona. Asegúrese de leer y señalar valorar todos los ítems de la lista. Haga las valoraciones en base a sus observaciones e interacciones con la persona en el último mes. Utilice las definiciones del siguiente cuadro para puntuar cada ítem.	
Este comportamiento se produce y es un problema leve	1. Este comportamiento no se produce
2. Está fuertemente apegado/a un objeto específico	2. Este comportamiento se produce y es un problema leve
Este comportamiento se produce y es un problema leve	3. Este comportamiento se produce y es un problema moderado
3. Está preocupado/a por la parte o partes de un objeto en vez de su totalidad (por ejemplo, los botones en la ropa, las ruedas en los coches de juguete)	4. Este comportamiento se produce y es un problema grave
Este comportamiento se produce y es un problema moderado	
4. Está fascinado/a o preocupado/a por el movimiento o cosas que se mueven (por ejemplo, ventiladores, relojes)	

*Note.* Preguntas= Questions; Definición= Definition of behavior; Valoración= Likert response type to each item

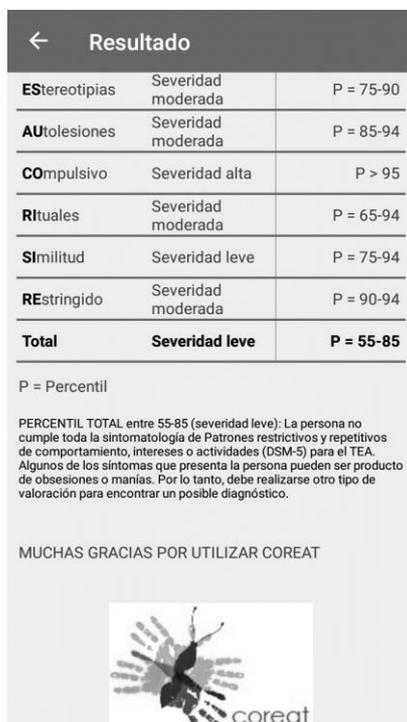
Figure 4. Start section

Results section: The psychometric results of the assessment are included for each dimension of the test. Percentiles and a description of the level of severity of repetitive behaviours are included (no problem, mild, moderate and severe levels) (see Figure 6). In addition, brief feedback on the results is added in the “Suspected ASD” profile (see Figure 7).



Note. ES= stereotypic; AU= self-injurious; CO= compulsive RI= ritualistic; SI= sameness; RE= restrictive behaviour; Severidad leve= mild severity level; Severidad moderada= moderate severity level; Severidad grave= high severity level; Total=total; P= percentile.

Figure 6. Results section



Note. ES= stereotypic; AU= self-injurious; CO= compulsive RI= ritualistic; SI= sameness; RE= restrictive behaviour; Severidad leve= mild severity level; Severidad moderada= moderate severity level; Severidad grave= high severity level; Total=total; P= percentile.

Figure 7. Results section (“suspected ASD” profile)

Assessment of the design: This included a descriptive pre–post survey to analyse the design of COREAT. The dates of the descriptive data collection were April and June 2019. Descriptive data on improving the design of the mobile application were collected through phone calls to participating families and professionals. All information on positive and negative aspects was recorded to make the changes.

#### *Participants and ethics*

The participants are from Spain, and the study focused on areas of the cities of Alicante and Murcia (Spain). Specifically, the participating professionals work in special education schools ( $n = 3$ ), an early care center ( $n = 1$ ), the pediatric department of a hospital in the city of Murcia ( $n = 1$ ), and at the University of Alicante and Miguel Hernández University of Elche as researchers ( $n = 3$ ). The participating families ( $n = 8$ ) were from Murcia. The total sample of individuals with ASD who were assessed was 11 (10 male and 1 female). The age range of the sample was between 4 and 18 years. The present study was approved by the Ethics Committee of the University of Alicante in Spain (reference: UA-2019-10-04). Participants received information on the mobile application (objectives, test execution time, ethics, etc.). All the information and a link to download COREAT was sent via WhatsApp. Participants were instructed not to send the link of the mobile application to other people. Informed parental consent was obtained. The characteristics of the 11 individuals with ASD in the sample are shown in Table 1.

*Table 1. Descriptive characteristics of the sample*

N	11
Age	$M = 7.9 / SD = 4.11$
Sex (m/f)	(10/1)

*Note.* M = Mean; SD = Standard deviation.

#### *Phases of the project*

##### *Scientific phase*

The RBS-R back translation, field study and database creation were carried out between 2011 and 2013. Subsequently, scientific base data was inserted in the mobile application (January-June 2014) and the psychometric properties and standard scores of the RBS-R were published (2015-2019).

##### *Development phase of the mobile application*

**Pilot tests:** There was continuous feedback from the multidisciplinary team (psychologists and software developers). The improvements suggested by members of the GINTA research group, software developers and other colleagues (teachers, professors, etc.) were implemented (April-May 2019).

**Testing real cases:** COREAT was then tested by performing individual tests of real clinical cases (June 2019). Furthermore, a survey on the intention to use and acceptability was obtained from the participants, both professionals and families (July 2019).

**Final feedback:** Final psychometric adjustments were made (August 2019), and after more feedback, COREAT was uploaded to the Play Store and App Store (September 2019).

#### *Measures*

**Intention to use and acceptability survey:** This instrument was developed *ad-hoc*. It contains a series of fields; objective, utility, structure, design and accessibility of the mobile application (see Table 2).

**Repetitive Behavior Scale-Revised (RBS-R):** This scale has been extensively described in the introduction.

#### *Assessment overview*

The feasibility and acceptability of the mobile application were analysed following observations made by professionals and families. In addition, intention to use and acceptability were analysed with a brief telephone survey (see Table 2). The survey was developed *ad-hoc* and was submitted to participants by a team member. All questions and answer choices were read to the participants. The answer options were dichotomous (yes / no). The maximum time to answer the survey was six minutes.

Table 2. Intention of used and Acceptability (pre-post-design evaluation)

Topic area	Professionals (n=8) %		Families (n=8) %	
	Pre-design	Post-design	Pre-design	Post-design
<b>Objective</b>				
They said that the objective of the mobile application was adequate	99	99	94	95
They said that the test instructions were clear	94	95	90	90
They said that the test measures a broad spectrum of repetitive behaviors	90	90	87	88
<b>Utility</b>				
They said that they would like to use it in the future	97	99	99	99
They said that they would like to spread the mobile application to other people	98	98	99	99
<b>Structure</b>				
They said that response format was appropriate	80	85	79	80
They said that the transition between items was adequate	82	87	81	85
<b>Design</b>				
They said that font size and colors were adequate	90	95	87	90
They said that graphics were clear and understandable	89	97	70	88
They said that wording of the results was clear	20	90	10	86
<b>Accessibility</b>				
They said that mobile application was intuitive and accessible	86	88	85	86

#### Data analysis

Descriptive statistics were conducted to analyse the pre-post survey of professionals and families. Qualitative feedback from the multidisciplinary team (psychologists and software developers), professional staff and families was reviewed and coded by a member of the GINTA research group. IBM SPSS-Statistics 22 for Windows (IBM Corp., 2013) was used. The main analysis consisted in calculating a student's t in the Pre-design and post-design on the intention of used and acceptability intention of used and acceptability of the COREAT. As a result, p-values of .01 or less were considered significant. Those differences with  $p < .05$  were considered significant. Cohen's (Cohen, 1988) criteria were used to assess the Effect Sizes (ES) of the correlations. In this case, the ES are considered small when the correlation was below .10, medium when it was between .10 and .30 and large when it was greater than .50 (Cohen, 1988; Lipsey & Wilson, 2001).

#### Results

The results indicate that there was a very similar percentage in the frequency of diagnosis. Thus, 100% of participants reported that the assessed person was diagnosed an ASD.

The comparison of pre-post survey intention of use and acceptability revealed a total pre-test average score of 84.09% for professionals and 80.09% for families (total: 82.59%). However, total post-survey average score was 93% for professionals, and 89.63% for families (total: 91.31%). Therefore, an increase in the percentage of intention of use and acceptability was found after the improvements made to the mobile application. A slight improvement was found in most areas assessed with the survey. The biggest improvement was the inclusion of brief written feedback on the results section (item: "They said that wording of the results was clear"). For this item, the initial test score was 15%, compared to the re-test average score for professionals and families, which was 88%.

Table 3 presents the means and standard deviations of the differences in intention of use and acceptability of COREAT. The post-design compared with the pre-design presented a significantly higher mean, with a high magnitude of difference.

Table 3. Differences in intention of used and acceptability

	Pre-design	Post-design	$t_{11}$	$p$	$d$
	M (SD)	M (SD)			
Intention of used and Acceptability	9.08 (0.30)	10.04 (0.30)	-41.10	.00	.98

Note. \*  $p \leq .05$ , \*\*  $p \leq .01$ ; M = mean; SD = standard deviation.

#### Discussion

The aim of this study was to describe the development of COREAT in Spain. A mobile application that allows the severity of repetitive behavior to be measured using the RBS-R test. The RBS-R is a scale with excellent psychometric properties (Martínez-González & Piqueras, 2018, 2019b) which could help learn the severity of the RRBs according to DSM-5 criteria (APA, 2013).

Several key aspects were taken into account to develop COREAT as a serious health mobile application: 1) Working with a multidisciplinary team (Baranowski et al., 2013); 2) Basing COREAT on a solid theoretical model (Bodfish et al., 2000); 3) Implementing a proper procedure, using input gathered during the development of COREAT (alpha and beta testing), to further adjust the mobile application. This development work helped to improve aspects such as: increasing the font size of words for better readability, including a feedback text for the "Suspected ASD" profile in the results section, etc.

The intention of use and acceptability improved after modifying the initial design of the mobile application. These results are consistent with others that have found improvements in the development of mobile applications with similar methodologies (Ruggiero et al., 2020). Feedback regarding intention of use and acceptability from professionals, families and assessment team members was important in clarifying psychometric (scale adjustment) and set-up needs. Lessons learned led to a better development of the mobile application.

The initiative to develop COREAT is an important contribution to educational and medical staff. In the same way, it makes an instrument based on scientific evidence accessible to families. This provides families with greater immediacy in the psychological assessment of their child. All these aspects have a direct impact on the early detection of ASD and the monitoring of autism cases.

### Conclusions

The development and pilot assessment of COREAT shows promising results. In general, the mobile application was found to be feasible and acceptable for professionals as well as families with a child who has ASD. Therefore, COREAT is an accessible app for both professionals' staff and families who have children with ASD. It has been shown to be a very useful resource for both the diagnosis and detection of ASD in the clinical and educational spheres. In addition, COREAT is a technological instrument for serious health assessment in autism without economic cost, and based on scientific evidence.

### Recommendations

Future studies should examine the psychometric properties of the RBS-R from the mobile application itself, attempt to increase the sample of diagnostic profiles and create a data warehouse on the cases analysed. Finally, the standard scores for the Latin American population with ASD is an important matter to investigate in future studies. Thus, an analysis of COREAT in a larger sample, in different countries, using other methodological approaches and measuring long-term data is needed in the future.

### Limitations

This study has similar limitations to those found in prior studies: 1) The common problem of small sample sizes for analysing intention of use and acceptability, 2) the mobile application does not store data on cases, and 3) it can only be used for the Spanish population with ASD. These limitations should be considered in future studies.

### Acknowledgments

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