Educational robots and their control interfaces: how can we make them more accessible for Special Education?

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Abstract. Existing design standards and guidelines provide guidance on what factors to consider to produce interactive systems that are not only usable, but also accessible. However, these standards are usually general, and when it comes to designing an interactive system for children with Learning Difficulties or Disabilities (LD) and/or Autism Spectrum Conditions (ASC) they are often not specific enough, leading to systems that are not fit for that purpose. If we dive into the area of educational robotics, we face even more issues, in part due to the relative novelty of these technologies. In this paper, we present an analysis of 26 existing educational robots and the interfaces used to control them. Furthermore, we present the results of running focus groups and a questionnaire with 32 educators with expertise in Special Education and parents at four different institutions, to explore potential accessibility issues of existing systems and to identify desirable characteristics. We conclude introducing an initial set of design recommendations, to complement existing design standards and guidelines, that would help with producing future more accessible control interfaces for educational robots, with an especial focus on helping pupils with LDs and/or ASC.

Keywords: Access to education and learning · Assistive Robots · Design for All best practice · Design for Children with and without disabilities · ASC · Learning difficulties · Learning disabilities · educational robots

1 Introduction

Current standards applying to the design and development of interactive systems, such as those created by the International Organization for Standardization (ISO) [18], provide requirements and guidelines to help designers and developers produce systems that are fit for their purpose. In terms of the creation of usable and accessible new technologies, there is an increasing number of ISO publications that provide guidance on the ergonomics of human-system interaction [12, 11, 26, 10, 9, 8, 7, 10, 25]. These standards are usually complemented with others related to software ergonomics for interfaces [18] and the accessibility of user interface components [13]. However, these standards are very general, and this is because they address all systems that involve human-system interaction and user interfaces. They clearly indicate that the needs of the end-user have to be taken into account, and that depending on the user the requirements of each system will be different. Nonetheless, they also require that all systems make a provision for allowing the use to those people with accessibility needs. This again is not very strict, because they also specify that when the nature or main objective of the system is lost or altered when making adaptations to ensure its accessibility, then, it is not required to make such adaptations.

The design of interactive systems may also be informed by more specific principles or guidelines, like Nielsen's ten "heuristics" for user interface (UI) design [23], as well as by advice given by organisations or institutions representing different user groups.

In terms of guidelines specific to accessibility, the Web Content Accessibility Guidelines (WCAG) 2.1 [20] and the more recent working draft [1] are normally the ones against which web accessibility is measured. However, these standards, principles, guidelines, and pieces of advice are usually general, covering a very wide range of uses for the system to be designed and developed. Whilst the WCGA guidelines [20, 1] address matters related specifically to accessibility, and their use could be extended to other interactive systems and not only web content, they do not look into the accessibility of more complex systems, such as those necessary for the control of robots, since these systems may involve not only a graphical user interface (GUI), but also the physical robots and any buttons or sensors that these might have. Furthermore, and although it is normally considered good practice to follow those guidelines, in many cases certain accessibility features are disregarded by designers and/or developers.

A possible reason behind paying less attention to the integration of accessibility features in control interfaces for educational robots, is that these interfaces are usually designed and developed for them to be used by programmers, by people learning how to code, or simply as games. The complexity of those interfaces targeted at programmers is usually high, which makes integrating certain accessibility features more complex. A similar issue occurs with interfaces aimed at people learning how to code. For those interfaces designed as games, and for games in general, the results of a recently published survey targeting professional game developers [16], reveals that only 39% of games developers have implemented accessibility measures (for those with sensory impairment, motor impairment, or other impairments) into their games. The report highlights that *"Unfortunately there is still a lot of pushback in implementing accessibility features"*, and most of the accessibility measures taken focus on hearing or visual impairments.

More recently, Qbilat and Iglesias have proposed accessibility guidelines specific to tactile displays in Human-Robot Interaction (HRI) [27], however, these focus on service robots, and whilst many of them can be applied to educational robots, the nature of the use of these devices varies.

As a field, Educational Robotics (ER) has been recently defined as *"a field of study that aims to improve learning experience of people through the creation, implementation, improvement and validation of pedagogical activities, tools (e.g. guidelines and templates) and technologies, where robots play an active role and pedagogical methods inform each decision."*[3], and therefore, the robots used with those aims can be considered educational robots.

Educational robots have been used from the 1980's as tools to assist with the teaching of subjects in the area of Science, Technology, Engineering and Mathematics (STEM) [24], and from the late 1990's as rehabilitation and education tools for children with ASC [22]. Nowadays, educational robots are mainly used to help with the teaching of STEM subjects, with an emphasis on programming and the logic behind it [19, 4, 21], but there is also an increasing number of studies and initiatives successfully introducing their use to help children with LD and ASC, focusing more on the later group [29, 2, 5, 30]. However, despite the advantages that educational robots offer to children with LD and/or ASC, recent studies have highlighted the lack of uptake for this technology in schools for children with Special Educational Needs (SEN), such as LD an/or ASC, mentioning, among other issues, the non-commercial availability and inadequate design of the interactive systems used to control them [17, 14, 15].

This paper presents an exploratory study where we aimed to answer the following research questions:

1. What are the main accessibility issues present in existing educational robots and their control interfaces?
2. How can future systems be made more accessible?

2 Methods

This paper presents the results of the analysis of existing interactive systems along with the results of focus groups with experts and an online questionnaire. The methods for each of them are presented.

2.1 Analysis of existing interactive systems

Design Analysis of existing systems looking at: capabilities of the control interface, main purpose and hardware needed to operate the robot.

Eligibility criteria For the educational robot system to be considered within this study, we applied the following eligibility criteria:

1. The system should be commercially available;
2. The system should have educational capabilities;
3. The system should include a robot and offer a clear way of interacting with it, such as an app that can be used from a mobile device or a computer, a remote, or buttons on the robot (i.e., not simply a turn-on, turn-off button or an autonomous robot);

4. A throughout description of the control interface should be available (i.e., from the manufacturer website, a manual, or a third-party review) or, for those where the control interface is an app and a detailed description is not available, the control interface should be freely available for us to download and check.

Procedure An initial selection of systems was drawn from a previous study [15], in which the five main reasons for low uptake of robots in Special Education were highlighted along with a table with information about different studies that used robots for interventions with children with Special Educational Needs (SEN). From that table we identified the three systems that met the eligibility criteria.

Since we did not want to limit the analysis to robots previously reported as used in research studies, we carried out a search in various online retailers of educational robots for other systems that met the eligibility criteria, even if these did not target children with SEN.

From both sources, a total of 26 systems were identified.

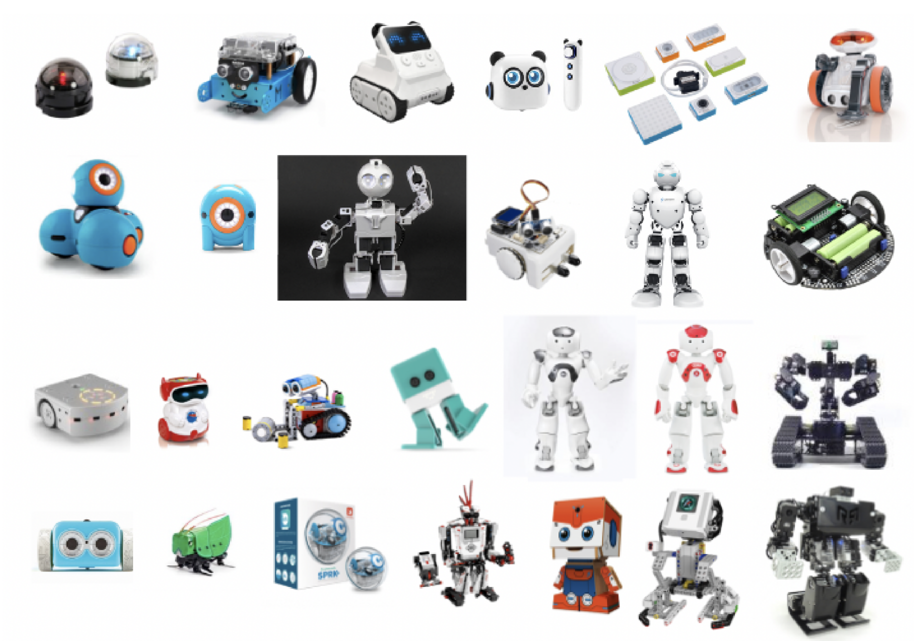

Fig. 1. Robots of the 26 systems analysed. Their names can be found in the first column of Table 1 and the order to follow in the image is row by row, from left to right and from top to bottom.

Analysis A member of the research team searched for information about each of the systems on the manufacturer's website as well as on retailers' websites. The information looked at included: the advertised main purpose of the robot, the control interface/s and the capabilities that it offered in terms of different activity types or ways of interacting with the robot, and the hardware needed to be able to interact with it. The characteristics of the systems as analysed can be seen in Table 1, and a picture of the relevant robots can be seen in Figure 1.

When a manual was available this was checked to gain a better understanding of the system being analysed.

In those cases in which an app was available for controlling the robot this was downloaded and explored to gain a better understanding of its capabilities, as well as of the potential accessibility issues that could be present in them. It is important to note that several apps were available to be downloaded and explored even if the relevant physical robot was not available to the researchers.

We took into account during the analysis the five main reasons of low uptake of robots in Special Education that were found during a previous study [15] to see if there was a clear evidence of any of them being present in the analysed systems. These five issues are: price, lack of user-friendly interface, lack of appropriate alternative ways of interaction for Special Education pupils, contents not being appropriate for Special Education students, and not being able to use different robots with the same control interface. When further expertise was necessary to determine if any of the issues was present with a specific system (i.e., expertise educating or living with children with SEN) this was sought during the focus groups with experts and parents described in the next subsection.

2.2 Focus groups with experts and parents, and questionnaire

Design Focus groups followed by an online questionnaire.

Participants Participants had to meet the following eligibility criteria to be able to participate in the study:

1. Be 18 years old or older;
2. Be an educator or expert in Special Education, through work-experience or training, or the parent or a close family member of a child with SEN;
3. Be fluent in either English or Spanish, as these were the languages in which the content and the focus groups would be presented.

A total of 32 participants were recruited across Spain and the United Kingdom (26 from Spain, 6 from the UK). Three of the participants were parents or close family members of a child with SEN at two different institutions, with one of them being the official Parents' Representative for the institution that the child attended. The total sample belonged to four institutions: a state-funded school for children with SEN in Toledo, Spain (6 participants); a partially state-funded school for children with SEN in Toledo, Spain (5 participants); the faculty

Table 1: Description of the educational robots analysed, the systems/interfaces used to control them, their main purpose, and the hardware needed to control them.

Robot	**Control interface and capabilities**	**Main purpose**	**Hardware needed**
Ozobot Evo and Bit	App: block programming, remote control, draw, drag & drop, coding cards	Teaching coding/programming	Computer or mobile device
Makeblock mBot series	App: block programming, remote control, piano game, draw, drag & drop	Teaching coding/programming	Computer or mobile device
MakeBlock Codey Rocky	App: block programming, remote control, remote programmer on robot	Teaching coding/programming	Computer or mobile device and physical buttons on robot
MakeBlock mTiny	Remote programmer with tap-to-code interaction, coding cards	Teaching skills through coding concepts	Remote similar to Nintendo Wii's controller
MakeBlock Neuron	App: block programming	Teaching coding/programming	Computer or mobile device
Mio The Robot 2.0	Remote programmer on robot	Teaching coding/programming	Physical buttons on robot
Wonder Workshop Dash	App: block programming, remote control	Teaching coding/programming	Computer or mobile device
Wonder Workshop Dot	App: block programming, remote control	Teaching coding/programming	Computer or mobile device
EZ-Robot (various models)	App: block programming, remote control, drag & drop to create interface, traditional coding/programming	Teaching coding/programming	Computer or mobile device
ArcBotics Sparki	App: block programming, traditional coding/programming	Teaching coding/programming	Computer or mobile device
UBTECH Alpha 1 Pro	App: block programming, traditional coding/programming	Teaching coding/programming, dancing, yoga	Computer or mobile device
Pololu 3pi	Traditional coding/programming	Teaching coding/programming	Computer
Thymio	App: block programming, traditional coding/programming, 6 pre-programmed buttons	Teaching coding/programming	Computer

Table 1 continued from previous page

Robot	**Interactive system used to control the robot**	**Main purpose**	**Hardware needed**
Doc Interactive Talking Robot	Remote programmer on robot	Teaching coding/programming	Physical buttons on robot
Tinkerbots My First Robot Educational Kit	App: simplified block programming	Teaching coding/programming	Mobile device
Zowi	App: block programming and remote control	Teaching coding/programming	Mobile device
NAO Robot	App: drag & drop to create complex behaviours, traditional coding/programming	Teaching coding/programming	Computer
ZoraBots NAO	App: remote control, text-to-speech, predefined drag & drop activities	Healthcare companion	Mobile device
Lynxmotion Johnny 5	App: servo controller interface	Teaching robotics	Computer
Botley The Coding Robot	Remote programmer, coding cards	Teaching coding/programming	Physical buttons on a remote
Mattel Kamigami Programmable Robot Kit	App: simplified block programming, remote control	Teaching coding/programming	Mobile device
Sphero robots	Apps: remote control block programming, traditional coding/programming	Teaching coding/programming	Mobile device
LEGO Mindstorms	Apps: remote control, simplified block programming, traditional programming	Teaching coding/programming	Computer and mobile device
MU SpaceBot	App: block programming	Teaching coding/programming	Mobile device
Abilix Krypton Modular Contruction Robot Kits	Apps: remote control, simplified block programming, block programming	Teaching coding/programming	Mobile device
RQ-HUNO Robotic Humanoid Kit	Apps: servo controller interface, action sequencing interface, traditional coding/programming	Teaching coding/programming	Computer

of education of the University of Castilla-la Mancha in Toledo, Spain (15 participants); and a state-funded school for children with SEN in Nottingham, United Kingdom (6 participants).

Procedure. Before the research activities commenced, ethics approval was obtained from the Faculty of Engineering Ethics Committee of the University of Nottingham.

To proceed with the recruitment of participants, four institutions from which recruitment for a previous study had taken place were contacted. Information about the current phase was given to the main point of contact, and they put us in touch with those that were interested in participating and met the eligibility criteria.

One in-person focus group lasting for approximately two hours was held at each of four institutions, three of them with 5-6 participants and one with 15.

During the focus group sessions, and after receiving informed consent from the participants, an initial presentation of the study was followed by an introduction to the results of the analysis of the 26 systems that can be seen in Table 1. Pictures and videos of the relevant systems were also shown to them, and a live demo of three representative systems that were available to the research team and their control interfaces. These systems were NAO Robot[3] (only for the focus group held in the UK), EZ-Robot JD[4], Wonder Workshop Dash[5], and a Sphero[6]. Participants were given the chance to ask questions about the systems presented to them and to try and interact with the ones that were available during the live demo. They were encouraged to share their thoughts whilst interacting with the systems. During the focus groups we asked them questions about the appropriateness of the systems for their use in Special Education. Among other questions we asked them how easy they found using the systems, if they would change anything and how, and if they would use them during a learning session with pupils with SEN or if they found any particular issues with them. We obtained permission to record the audio of two of the focus groups, during the other two, detailed notes were taken to ensure that relevant themes and opinions could be identified during the analysis. The focus groups were organised close in time and were run by the same researcher, which allowed to maintain consistency and facilitated the note-taking process.

At the end of the focus groups, an online questionnaire was sent to participants to help us identify more specific requirements for the design of interactive systems used to control educational robots, paying especial attention to usability and accessibility aspects of the design.

Analysis. The analysis was performed in three stages.

[3] https://www.softbankrobotics.com/emea/en/nao
[4] https://www.ez-robot.com/learn-robotics-getting-started-humanoid-robot-kit.html
[5] https://uk.makewonder.com/dash/
[6] https://sphero.com/collections/all/products/sphero-sprk-plus

First, a researcher transcribed and analysed the audio recordings of the two focus groups that were recorded, along with the notes taken during the other two focus groups. Initial codes were assigned to then lead to the main themes that could, as described by Braun & Clarke [6], capture important information about the data in relation to the research question and represent meaning within the data set. A set of themes was defined, as well as extracts from the transcripts or the notes that represented each theme.

Further to the thematic analysis of the focus groups, the answers provided to the questionnaires were analysed. Some of the questions allowed for free-text answers. In this cases we explored if these fitted within the themes identified in the previous stage or if new themes arose.

A final exercise of consolidation of the results of the two prior stages was done to ensure that a final list of design recommendations could be produced.

3 Results

3.1 Analysis of existing systems

Main purpose of the system. We observed that most systems (23 of the 26 analysed) focused on teaching coding/programming skills and the logic behind it. Of the remaining 3, 1 was aimed at teaching robotics focusing more on the hardware side of the discipline, and 2 had a focus to act as healthcare companions or to teach other activities.

Interactive system used to control the robot. The main control method offered by 14 of the 26 systems analysed was an app with a block programming interface (see Table 2), which is the representation of coding concepts as interlocking blocks similar to puzzle pieces that are combined to create larger, more complicated sequences of actions. 17 systems offered various control systems using an app for a mobile device such as a smartphone o tablet. However, upon downloading and trying the apps, these could not be successfully controlled using embedded accessibility features provided by the device's operating system (usually called Switch Control or Switch Access) and therefore required the user to be able to interact with the screen of the device via drag & drop gestures.

5 systems could only be used from a computer, with limited control or functionalities when using assistive technologies, and 4 systems had to be used with a physical remote programmer.

For those systems that used a control interfaced based on block programming, these were nearly identical, however, despite this fact, in all cases, each app or control interface could only be used with the robots from the same manufacturer.

3.2 Focus groups with experts and parents and questionnaire

Four main themes that relate to our question on how to make educational robots and their control interfaces more accessible were identified after the consolidation

Table 2. Number of interactive systems offering each type of control system

Type of control system	No. of systems (total = 26)
Block-programming	14
Drag & drop of pre-existing activities	4
Coding cards	4
Remote programmer not on robot	3
Remote programmer on robot	4
Remote control through app	11

of the results from the focus groups and the free-text questions in the online questionnaire. These are:

1. Assistive technologies
2. Layout of User Interface (UI)
3. Purpose/activities offered
4. Physical aspects of the robot

Further to this, the results of the questionnaire answers to more specific questions related to the requirements for a desirable system are presented.

Theme 1: Assistive technologies. Participants believed that some of their pupils could successfully interact with a mobile device using drag & drop gestures without the need for assistive technologies, but that this was limited to those that had better fine motor skills. Some indicated that being able to control the robot could serve as an incentive for some pupils to work on improving them, but that limiting those interaction to drag & drop was not the best approach, as it would exclude many children. Regarding this, and after discussing the case of children with limited mobility that need to attend physiotherapy sessions for cervical rehabilitation, one participant said:

"For many children it is more interesting to work on some things through play, rather than for instance working on them with the physiotherapist, it is different".

When we asked specifically about whether or not they considered that existing interfaces were accessible enough, they highlighted that they are not accessible enough for a Special School.

The three schools taking part in the study had several pupils that could only move their eyes, and therefore thought that more should be done to make the interfaces more accessible. Participants highlighted that they were already using assistive technologies such as micro-switches, eye-trackers or devices that kept a screen on if the child maintained their head up (for those following cervical rehabilitation), and that it would be great it those devices could be used with a robot.

"In our classrooms we do have micro-switches, then, that's it, depending on the characteristics of the child, if they can use a bigger or smaller switch, or

even if they can use it only with one finger or with the whole hand, then... it would be really motivating".

Participants mentioned as well that, whilst some of the interfaces could be used by the educators to trigger certain actions on the robot even if the child could not operate it, this was not ideal:

"It is not that much that teachers used the robots to teach the children, but that the children could use the robots themselves, that they could learn with them themselves".

Theme 2: Layout of User Interface (UI). When it came to control interfaces for the robots, participants found more interesting the use of apps than the use of buttons on the robot or on a remote, and some did not feel that it was safe for the robot to be handled/touched by some of their pupils:

"Our pupils... that, some of them interact with things with slaps and, imagine! rraass! to the floor, and the materials they are made of are so rigid...".

Participants indicated that, in most cases, items on the screen were very small and that, even those pupils that could successfully interact with the interface without assistive technologies would likely find it too difficult.

"I don't know you, but I find those buttons too small even for me, look at all that empty space on the screen".

They also highlighted that the icons used to depict the action that a button would trigger were in some instances confusing. Whilst testing some of the apps themselves, one participant was very vocal in that regard, asking other participants if they knew what some of the icons meant, because they didn't.

When talking more specifically about block programming, participants in general found very interesting that you could program your own activities using the interface. However, they believed that without proper training or enough time to get familiar with the interface, it could be confusing, and that it requires to dedicate time and effort to create any activities that they could later use with they pupils:

"It's not just creating the activity in the app, I'd have to, I don't know, learn how to create anything with it first, then think of an activity that I could make, and then make it, and what if after having designed the activity I see that I cannot create it with the blockly?".

An issue highlighted relating to the layout of the UI was that participants considered that most apps had too many unnecessary distractions on screen, which could lead to attention problems for pupils.

Theme 3: Purpose/activities offered. In general, participants felt that, whilst some pupils could benefit from learning how to code or the logic behind it, for their pupils this was not appropriate at a cognitive level:

"We have pupils with a very low cognitive level, then there are children that, precisely, you can expect a really light response from them, and so it's what it is, basic responses, but these things (of the robots) catch their attention".

They also indicated that these technologies could be used to teach them how to anticipate things that would happen during the day, and that it was not a matter of being able to create complicated activities, that sometimes simple ones can be used to teach many concepts:

"Many times, with showing them, I don't know, a plate, a child can learn that after that we are going to see the menu because it's nearly lunch time or things like that, activities as simple as that, you can adapt it a bit to the different activities that the school does".

Participants felt as well that the ideal would be to be able to load pre-made activities onto the app and the robot:

"Having a bank of activities that you could load and use would be very useful, and that you could get and use those activities without needing to code. That would save on work or at least make that work easier... it would be quicker."

Theme 4: Physical aspects of the robot. Participants did not limit themselves to commenting on the control interfaces for the robots. Some physical aspects of these were also considered an issue.

During the demo of one of the robots, participants observed the use of flickering lights by one of the default behaviours of a robot, and they emphasised the importance of either adding a warning or disabling any flickering light by default, as this could negatively affect people with epilepsy.

In one of the focus groups it was also mentioned that robots that use ultrasounds to communicate with a control device should likely be avoided in Special Schools:

"It's supposedly designed for a school environment. It can interfere mainly with hearing aids. Sometimes my child says: dad, that sound is very loud; and I tell him: what a hearing sense you have! I can't hear anything! With young children that must be... don't use it, that really caught my attention".

Participants also raised privacy concerns regarding the existence of cameras in some of the robots, and one participant suggested he would tell others to *"put a piece of tape"* on the camera before using it in a school. Another participant suggested the avoidance of Internet connection from the robot and to use Bluetooth connectivity to communicate with its control interface instead.

Another aspect that was already mentioned within Theme 2 is that the robots seem to be made of very rigid materials and thus are not very robust for them to trust that a child would be able to interact with it via touching its sensors or buttons without damaging it.

Other questionnaire responses. From the responses to the questionnaires that participants filled in after the interviews, we observed the following:

- 27 of the 32 participants recommend the colour combination of black and yellow for a Graphical User Interface (GUI). The other 5 participants each recommended a different colour combination different from black and yellow (see Figure 2).

- 22 participants recommended to use round-shaped buttons in the interface instead of those with other shapes.
- There was no consensus on whether the font type to use should be upper or lower case, and normal or bold face.
- The two font faces identified as the best to use were Comic Sans and Arial (see Figure 3).
- There is a general consensus on the need to include characteristics such as: 1) showing circular buttons on screen; 2) allowing the user the configuration of the number of buttons to have; 3) showing pictograms, although again, there is no agreement on the type of pictograms to use; 4) offering alternative ways of interaction; 5) not requiring Internet to work; 6) being able to create user profiles for pupils; 7) Allow access to pupil's profiles to their teachers and parents; 8) being able to use the same system to control different robots; 9) offering rewards to the pupils; and 10) not requiring any coding/programming knowledge to be able to use the system effectively.
- In Table 3 we can see the assistive technologies that participants recommended to integrate as compatible with these systems, and how many participants recommended each of them.
- In Table 4 we can see how many participants recommended each feature to have in the pupil's profile.
- In Table 5 the activities that participants recommended it would be desirable to have in the interactive system can be seen.
- As last factors to be taken into account, we can see in Table 6 the types of rewards that participants recommended the robots should produce when a pupil performed well enough in an activity.

Table 3. Number of participants that recommended compatibility with each assistive technology

Assistive technology	**No. participants (total = 32)**
Eye-tracking	26
Movement-tracking	23
Switches	21
Speech	21
Sound	17
Sip'n puff	16

3.3 Design recommendations

Do not focus on solely one way of interaction. It is important to create a system that can gather for different ways of interaction such as control through eye-tracking or movement tracking. This is because a great number of children with SEN also have accessibility needs that make their use of tablet screens, for instance, more difficult or even impossible.

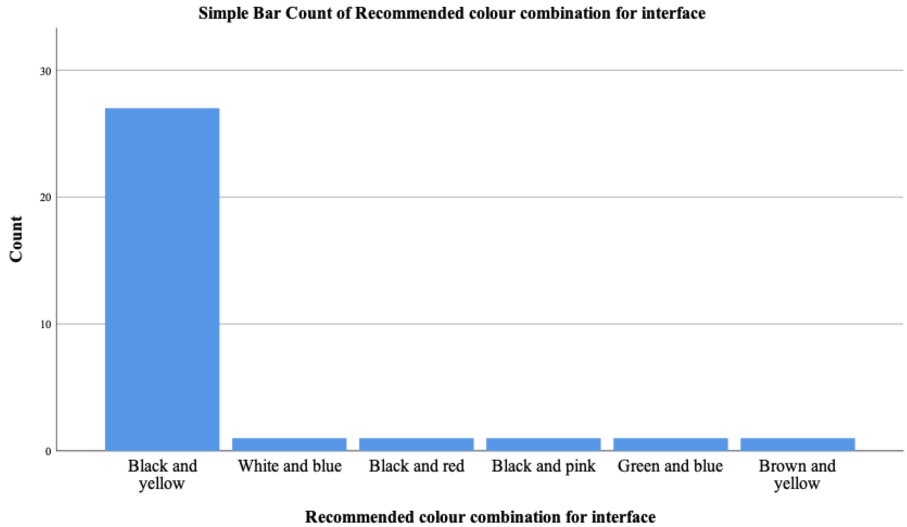

Fig. 2. Black and yellow is the colour combination recommended by most participants

Table 4. Features recommended by participants to have in the pupil's profile

Features	**No. participants (total = 32)**
Favourites activities	24
Characteristics and preferences	23
Buttons preferences	22
Font type preferences	14
Score	14
Notes and comments	12

Check the compatibility of the system with accessibility features embedded into the operating system of the device being used, or separately with assistive technologies. There are numerous assistive technologies that are already compatible with the most widespread operating systems. Very often it is only necessary to check that the system or app being developed complies with the accessibility guidance given by the developer of the operating system.

For a Graphical User Interface (GUI) use preferably black text over yellow/cream background. This colour combination has been suggested as the one that works best for children with SEN. It is important to pay attention to the the contrast as well.

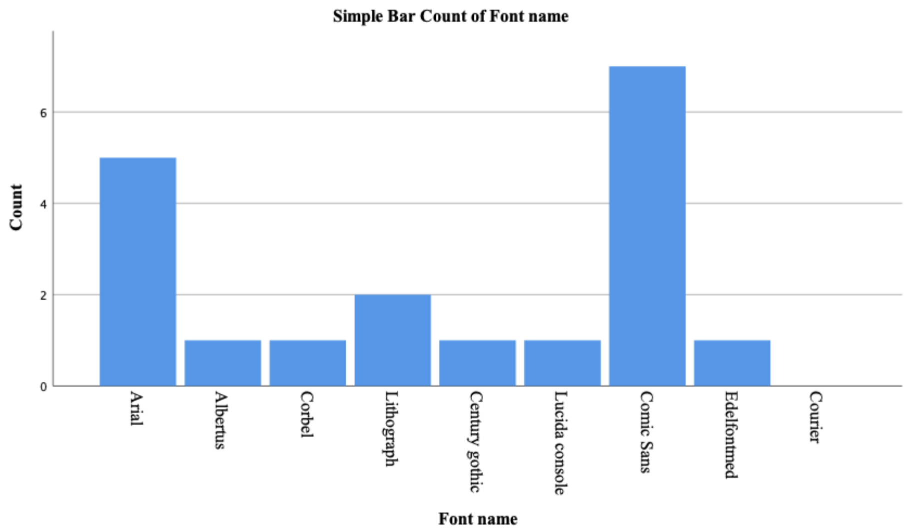

Fig. 3. Questions such as the font face to use didn't receive a consensus in responses even after comparing between institutions

Avoid the use of flickering lights. In Special Education settings it is very possible to find children with epilepsy. It is better to incorporate this feature as an option that can be enabled if the user of the system knows that it is not going to cause any harm to them.

For a GUI, use circular buttons that fill well the screen. A circular shape has been recommended for buttons, as it is a shape that children can more easily associate with the action of a button (it resembles a physical button). It is also recommended to avoid big empty gaps in the screen unless this is required for a particular reason.

Complement the text on screen with pictograms that convey a clear meaning. Not all children can read, and not all can see a screen correctly. Therefore, it is very important to complement information given in the form of text with pictograms that convey the same meaning in a clear manner. This will enable an easier interaction with the system and will help children learn what the text that accompanies each pictogram means.

Avoid reliance on an Internet connection. Many schools do not have a reliable Internet connection, and many families do not feel safe leaving their children using a device connected to the Internet.

Table 5. Types of activities recommended by participants

Types of activities	No. participants (total = 32)
Social interaction	29
Daily life	26
Q&A customised by teacher or parent	26
Imitation	25
Directions and navigation	24
Numbers and mathematics	23
Colours	19
Language	16

Table 6. Types of rewards recommended by participants

Types of reward	No. participants (total = 32)
Cheering sentences	22
Dances	19
Custom sentences	19
Custom sounds	17
Sounds	16
Cheering movements	16
Custom songs	15
Lights	15
Predefined songs	11

Provide personalisation options and user profiles for different users. It is very important to take into account that each user is different, and that although these recommendations are meant to make the development of systems easier for their use by children with SEN, personalisation options should be provided whenever possible.

Make systems compatible with more than one robot. This will allow schools and families to use in an easier way a wider range of educational robots without the pressure to acquire and learn how to use different control interfaces for nearly the same purpose.

Implement different rewards for the pupils. Rewards, delivered as dances, sounds, songs, or encouraging sentences, among others, should be included in every system that is going to be used by children with SEN. Many children with SEN need this kind of stimulus to be keen to continue with a learning session.

Do not require users to have to code or to understand the logic behind programming. Many teachers and parents do not feel comfortable using educational robots because it is usually a requirement to at least understand the basis of programming, even if this is done through block programming. Whenever possible this should be avoided, and users should be provided with alternative ways of using their robots.

4 Discussion

Whilst this study was limited by not being able to physically access and thoroughly evaluate all of the analysed robotic systems, it has allowed us to gain a better understanding of the main accessibility issues that educators and parents of children with SEN see as barriers for the uptake and use of educational robotics in Special Schools as well as their potential.

The results match the findings of a previous study [15] that highlighted that the lack of contents appropriate for Special Education pupils, with most systems focusing on teaching coding, was one of the five main reason of low uptake of this technology by Special Schools, and where the lack of compatibility with assistive technologies to provide alternative ways of interaction for those with Severe Learning Difficulties (SLD) or Profound and Multiple Learning Difficulties (PMLD) was considered as an important barrier for uptake. Furthermore, during that same study, something that our participants observed was also highlighted: needing a different control interface for each robot was "confusing" and also a factor affecting negatively the uptake of robots in Special Education.

The opinions of the participants given during the focus groups and in the questionnaires resonate with recently proposed HRI accessibility guidelines by Qbilat et al. [28]. These guidelines were evaluated with HRI designers and/or developers instead of with potential users of the systems and were focused on socially assistive robotics. However, and although we present some more detailed recommendations specific to the use of educational robots in Special Education, the fact that there is an overlap between them seems to indicate that similar accessibility issues have to be tackled in both cases.

Some robots can be considered expensive, but participants indicated that the value-for-money that these offer is more important than their price alone, and that, although currently it is difficult to justify the purchase of some of the robots based on some of the issues highlighted, if future control interfaces take into consideration the recommendations given in this paper, the value that these robots offer to Special Schools may increase, as more pupils and educators would be able to benefit from using them.

This study has allowed us to identify the main accessibility issues present in existing educational robots and their control interfaces from the perspective of Special Education, as well as to gather a set of recommendations that the designers of future systems could follow as an initial guide, along with existing guidelines and standards, to ensure that their systems are fit for purpose when it comes to using them with children with SEN. We believe that it is important to recognise the role of educators and parents when a new technology is to be introduced in the classroom, and consequently, their opinions and recommendations should be considered.

Future directions could take us to explore the same issues from the perspective of a designer or developer, as well as to a formal evaluation of an interface designed following the recommendations given.

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