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SURVEY ARTICLE

Collaboration Support in Co-located Collaborative Systems for Users with Autism Spectrum Disorders: A Systematic Literature Review

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ABSTRACT

Individuals with Autism Spectrum Disorders (ASD) often display difficulty in social interaction, verbal and non-verbal communication skills. They often have problems with recognizing and interpreting gestures and mental states of others, which restricts their capacity to understand implicit information essential to the social awareness and, consequently, the performance of collaborative activities in face-to-face situations (co-located collaboration). This study aims to identify, using a systematic literature review, how co-located collaborative systems designed for individuals with ASD provide the users with collaboration support mechanisms to encourage the performance of collaborative activities and interaction with their partners. Twenty-six studies from six electronic databases between the years 2006 and 2018 were selected and analyzed. Results evidenced the inclusion of different strategies to enforce or stimulate the collaboration among users, although there is a lack of resources for collaboration support as well as of studies designed specifically for individuals with severe ASD.

1. Introduction

Collaborative systems are computer applications that support the work of a group of individuals, interacting purposefully, to achieve a common goal (Kolfschoten & De Vreede, 2009). These systems provide collaboration support for improvement of the quality and efficiency of collaborative work and for participation and feedback of users (Nunamaker et al., 2015). Collaboration support refers to a set of information and interface resources that offer support for awareness and facilitate the collaborative performance in a shared workspace. Adequate support for awareness allows users to align their activities with other people's activities (Belkadi et al., 2013) and properly adjust their tasks to what their peers are doing in the workspace (Schmidt, 2002), thus allowing a successful collaboration.

In co-located collaborative systems, typically-developing individuals may be more aware of others' actions, intentions, and emotions; thus, the collaborative activity occurs naturally, through verbal and gestural communication. A significant challenge is to design collaborative systems for individuals that show difficulty in understanding the basic concepts of a collaborative activity, including in face-to-face situations (co-located collaboration) (Li et al., 2014). This is often the case of individuals with Autism Spectrum Disorder (ASD) who often show difficulty in perceiving and interpreting what others are doing or feeling (Salle et al., 2005). According to their type of impairment and severity of ASD, they have difficulty in recognizing body expressions and identifying others' mental states, limiting their capacity for understanding signs and implicit information that are essential for other-awareness and, hence, for social interaction and collaborative activities.

Studies in the literature involving co-located collaborative systems for individuals with ASD show interesting results regarding the benefits of these systems to encourage communication and social interaction skills (Chen, 2012; Gillette et al., 2007; Kientz et al., 2013; Millen et al., 2011; Noor et al., 2012). However, it is not clear how these systems provide collaboration support proportional to the level of difficulty experienced by users with ASD. With a view of identifying how researchers meet this challenge, we carried out a systematic literature review which aims to identify how to co-locate collaborative systems designed for individuals with ASD to provide appropriate collaboration support for these users.

It is worth noting that this review is part of a larger body of research which aims to develop collaborative systems for users who have serious difficulty in social awareness and performance of collaborative activities in face-to-face situations, such as individuals with high impairment in ASD. Thus, this review focuses on co-located collaborative systems that have been designed for face-to-face interaction because of their advantages in the natural interaction among users (human collaborators). Face-to-face interaction allows users to have a high awareness of others' actions in the shared interface (Sharma et al., 2016). Moreover, users can relate what they are doing to what others are doing based on the gestures or postures of the collaborators. Accordingly, our review does

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not include studies on remote collaborative systems, nor on systems where collaboration happens among real users with non-human characters or robots.

We examined what methods/strategies are employed in the systems to support the collaborative work and thus, to stimulate collaboration among ASD users with their peers; what the collaboration support offered; and what the design recommendations are for co-located collaborative systems.

We verified from the results of a search carried out in six scientific electronic databases that the systems assessed used different strategies or restrictions to enforce or encourage collaboration among users. These strategies have provided positive results concerning the stimulation of communication and social interaction skills among the participants. Even though these systems were developed for individuals with ASD, they do not explicitly mention offering collaboration support. We also verified a lack of studies specifically designed for individuals with severe ASD.

The rest of this paper is organized as follows: Section 2 describes the collaboration process followed by the Autism Spectrum Disorder description; Section 3 presents the systematic literature review process; Section 4 details the results of the review; and finally, Section 5 presents the conclusions.

2. Background

2.1. Collaboration process

According to the 3 C Model (Fuks et al., 2008), the collaboration process consists of the relation between three dimensions: cooperation, communication, and coordination. Cooperation refers to interventions made by the participants in the shared workspace with the aim of achieving a common goal. Communication entails a conversation by message exchange (spoken, textual, or physical) between the participants. According to Santarosa and Bicharra (2011), a fundamental requirement of communication is establishing a protocol, which the language specific to a particular domain or level of shared knowledge (common ground), for the participants to understand each other. Santarosa and Bicharra (2011) suggest that common ground ensures that all participants comprehend the language in the same manner and that all of them can understand each other. They highlight that comprehension is usually richer in face-to-face interaction as compared to computer-supported remote interaction (Santarosa & Bicharra, 2011). Coordination consists of the management of the participants, activities, and resources (Fuks et al., 2008; Pimentel et al., 2006). It certifies that group work is the sum of all individual efforts and that the result of such collaboration is productive.

A fundamental factor contributing to the appropriate execution of the collaboration process is awareness. Through awareness, individuals obtain a response to their actions (feedback), as well as a response to the actions taken by the other participants in the shared space (feedthrough) (Fuks et al., 2008; Pimentel et al., 2006). Awareness suggests users' overall understanding about the state of a shared environment, including knowledge about the people that share the environment, their interactions, the state of the shared elements, and collaborators' tasks, ultimately aiming to complete their own tasks satisfactorily (Belkadi et al., 2013). The knowledge of such context ensures that individual actions are relevant for the group's activity and objective (Dourish & Bellotti, 1992). Therefore, a collaborative system should offer all the necessary support for the actions of users. Hence, users should perceive who is interacting within the system, which alterations were made and by whom, and identify how these alterations were made and why.

2.2. Autism spectrum disorder (ASD)

The diagnostic criteria of ASD are in a perpetual process of revision due to research being conducted continually in an effort to better understand the spectrum. According to a clinical approach in the recent Diagnostic and Statistical Manual of Mental Disorders (DSM-V) (American Psychiatric Association, 2013), ASD encompasses different conditions characterized by atypical development, inflexibility of behavior and deficits in verbal and nonverbal social communication skills (American Psychiatric Association, 2013).

On the other hand, the Neurodiversity Approach advocates that ASD be seen as an expression of human diversity and not as a pathology. With this approach, neurodiversity highlights the strengths that individuals with ASD have, such as creativity, prodigious memory, visual-spatial skills, and exceptional talents in specific areas (Benton et al., 2014).

While individuals with ASD have varied strengths, they often display difficulties in initiating and response social interactions because they usually are not able to perceive others as partners in social interactions. This lack of awareness becomes obvious when individuals with ASD do not act according to the actions of other people, or present disturbed attention patterns when engaging in social activities (Holt & Yuill, 2014). These aspects affect their capacity to interpret and relate to the world around them and actively participate in socio-collaborative activities. The resulting lack of socio-collaborative activity accounts for the fact that they show impairment in the Theory of Mind (ToM), which is defined as the capacity for attributing mental states to themselves and others. ToM refers to individuals' ability to establish precise assumptions about other people's thoughts and feelings, which allows them to anticipate what others will say or how they will act (Bennett et al., 2013).

Each individual has different impairment levels in the affected areas and, therefore, different levels of ASD severity. According to the DSM-V (American Psychiatric Association, 2013), ASD is classified in three levels of severity: Level 3 "requires very substantial support," Level 2 "requires substantial support," and Level 1 "requires support." Level 3 is the most severe form of ASD; individuals diagnosed at this level display severe deficits in social communication skills, absence of or impairments in language, and minimal ability to engage in social interactions. Individuals diagnosed at Level 2 have moderate symptoms, showing deficits in verbal and nonverbal social communication skills, and limited ability to initiate social interactions. Individuals at Level 1 show difficulty with social communication skills and initiation of social interactions (American Psychiatric Association, 2013).

Individauls with varying levels of ASD have varying levels of cognitive impairment and learning disabilities (Weitlauf et al., 2014). Some of them may exhibit moderate or severe cognitive impairment (IQ < 70) or, on the contrary, exhibit cognitive abilities average or higher than average (IQ >70) (De Giambattista et al., 2019). High-Functioning Autism (HFA) is a term used to identify people with ASD that have language delays without additional cognitive impairments (Montgomery et al., 2016). Another term widely used to refer to a high-functioning form of ASD is Asperger's Syndrome (AS). Individuals with HFA/AS may have high intelligence and language skills without any significant learning disabilities (Mazzone et al., 2012); language is formally adequate but often monotonous and poorly communicative (Vannucchi et al., 2014).

Some studies outlined in this review provide information about the affected areas in the ASD users evaluated, but they do not specify their level of ASD impairment. Other studies involving people with ASD and cognitive impairment used the terms Low-Functioning Autism (LFA) and Moderate-Functioning Autism (MFA), referring to people with severe and moderate cognitive impairment, respectively.

3. Systematic literature review

The systematic review of literature demands a rigorous inspection for assessing a certain research topic (Kitchenham, 2004). In this study, we follow three stages proposed by Kitchenham (2004) for systematic reviews of software engineering research: planning, revision development, and review report. Planning includes the research questions and strategies, as well as inclusion and exclusion criteria. The development of the review describes how we conducted the review, including the databases and studies selected. Finally, the review report details the analysis of the selected studies to obtaining answers to the research questions. This last stage, which encompasses the results, will be presented in Section 4.

3.1. Review planning

In this stage, we identified the review's scope, the research questions, the strategy used for the systematic review, and the criteria for establishing the inclusion and exclusion of the papers found in the search.

In the context of collaborative systems intended for individuals with ASD, the technologies used include collaborative virtual environments (CVE) (Millen et al., 2011; Moore et al., 2005), robots (Wainer et al., 2010), shared surfaces such as multitouch tabletops (Chen, 2012; Millen et al., 2011), tablets (Holt & Yuill, 2017), and tangible user interfaces (TUI) (Villafuerte et al., 2012). Among these, we limited the scope of this review to studies including computational collaborative systems that allow a face-to-face interaction among real users to perform the collaborative work (co-located collaborative systems), facilitating other-awareness. This narrowed scope aims to identify how those computational systems support collaborative work among co-located users and encourage their social interaction skills while solving a problem together in the same virtual workspace. Thus, this review excludes both studies in which users interact with virtual peers (CVE) or robots and studies on collaborative systems that do not provide a shared virtual workspace (e.g., (Farr et al., 2009)).

According to the above criteria, the research questions to achieve the proposed objective are:

Q1. What strategies in the literature utilized the co-located collaborative systems to encourage the collaborative work of individuals with ASD who have difficulties interacting with others?

Q2. What collaboration support mechanisms (information and resources in the interface) are offered by the co-located collaborative systems intended for individuals with ASD?

Q3. What are the proposed/recommended requirements described in the studies for the design of co-located collaborative systems for individuals with ASD?

For the selection of the studies, we chose six electronic database sources: IEEE Xplore, ACM Digital Library, Science Direct, SpringerLink, PubMed, and SAGE Journals. The reason for choosing these sources is that they store a substantial amount of research in the area of computer science, together with psychology, health, and education areas. The steps employed in the research strategy are detailed in Table 1.

We defined the following inclusion and exclusion criteria for the selection of studies:

Inclusion Criteria:

- Studies published in the last twelve years (from January 2006 to December 2018).
- Studies on all co-located collaborative systems intended for individuals with ASD.
- Studies on co-located collaborative systems that involve different levels of ASD, including Asperger syndrome and HFA.
- Studies that present an evaluation process of the system, involving at least one ASD user interacting with another user(s).
- Studies published in journals or conference proceedings.
- Studies available with full access.

Exclusion Criteria:

- Studies for which full article is not available (only the title and the abstract).
- Studies on co-located collaborative systems exclusively designed for typically developing individuals.
- Studies on remote collaborative systems.
- Studies on systems based on immersive virtual environments or systems that require the interaction of one ASD user with non-human collaborators (e.g., robots or virtual characters).
- Studies on collaborative systems that do not provide a shared workspace, e.g., some TUI applications.
- Duplicate studies found in more than one database.

Table 1. Research strategies.

1. Search	Search in the six databases to find the studies.
2. Initial Selection	Selection of the studies found in step 1 based on reading the titles and/or abstracts, according to the inclusion and exclusion criteria defined in the research questions.
3. Final Selection	Selection of the studies after fully reading the papers found in step 2, and according to the defined criteria.
4. Data Analysis	Data Collection, tabulation, and analysis.

3.2. Revision development

For the review, we searched the entire electronic databases of IEEE Xplore, ASC Digital Library, SAGE Journals, and PubMed. As for Science Direct and Springer Link – as they involve several areas – we narrowed the topic of the search to "autism" and type of text to "article".

In order to obtain answers to this study's research questions, we believed it necessary to examine in detail the collaborative systems found in the literature. Therefore, the criteria adopted for the keywords search does not include compound nouns such as collaboration characteristics, support, or strategies. We included only generic words, and hence, the keywords were: "collaboration" and "autism."

To optimize the search, we built a search string from the keywords and their synonyms, using the logical operators "and" and "or," according to the particular writing strategies of the string in each database, without altering the search meaning. As an example, the string used for the ACM Digital Library is shown below:

((("collaborative") OR ("collaboration") OR ("groupware") OR "cscw") AND (("autism") OR ("autistic") OR "Asperger"))

From the six electronic databases, were retrieved 6590 papers overall using the string (Table 2). The papers include different types of studies about collaboration aspects (Figure 1), though only one type covers co-located collaborative systems, which is the focus of this study. We did not include studies that understand collaboration just as a joint action between researchers and end-users to design systems for individual use.

Papers retrieved as a result of this search were reviewed by one of the researchers who, after reading the titles and/or abstracts, selected 105 studies. Finally, after closely reading each one of them, the same researcher identified 26 studies as relevant according to the research questions raised by this systematic review.

Figure 1 shows, in a gray background, the types of studies selected from the total amount retrieved. We analyzed and described these studies in the next section in detail.

4. Results and discussion

From the 6590 papers initially retrieved, we noticed, within the time frame assessed (2006–2018), an increase in the number of collaborative systems that were developed and designed for individuals with ASD as the years progressed (Figure 2). Among these studies, we selected 25 papers published from 2009 to 2018 and one (1) study from 2006. Most of the selected studies range from 2012 to 2014 (13 of the 26 selected studies).

Table 2. Studies retrieved and selected from each of the databases from 2006 to 2018.

ELECTRONIC DATABASE	Retrieved Studies	Selected from Title/ Abstract	Selected after fully reading
IEEE Xplore	433	24	4
ACM Digital Library	94	34	12
Science Direct	141	14	4
SpringerLink	3232	17	4
SAGE Journals	2455	14	2
PubMed	235	2	0
Total	**6590**	**105**	**26**

Notably, 5 of the 26 selected papers refer to co-located collaborative systems for individuals with ASD that were addressed in other papers, but we decided to include them since they describe a different evaluation process with users or a different research perspective.

Of the selected articles (see Appendix), the majority (16) were published in conference proceedings and the others in journals.

The selected papers present the design and assessment of systems created for collaborative games, puzzle-style games, or storytelling activities intended for individuals with different levels of ASD and with ages between 5 and 22 years (Table 3). Most of the studies assessed users without specified ASD levels (Battocchi et al., 2009; Boyd et al., 2015; Holt & Yuill, 2017; Marco et al., 2013; Ribeiro et al., 2014; Roldan-Alvarez et al., 2014; Villafuerte et al., 2012; Wadhwa & Jianxiong, 2013) (Table 4) or users with HFA (Bauminger-Zviely et al., 2013; Ben-Sasson et al., 2013; Dillon & Underwood, 2012; Gal et al., 2009; Giusti et al., 2011; Hourcade et al., 2012, 2013; Marwecki et al., 2013; Piper et al., 2006; Weiss et al., 2011; Winoto et al., 2016) (Table 5). Six studies describe games (Table 6) specifically created for users with more severe levels of ASD and cognitive impairment (Farr et al., 2010; Keskinen et al., 2012; Silva et al., 2015, 2014; Silva-Calpa et al., 2018). A single study assessed with both HFA and LFA users (Tang et al., 2017).

The analyzed studies presented evaluations involving groups of two to six users collaborating in the same workspace. Among these, some studies involved collaboration among groups of children consisting of both those diagnosed with ASD and typically developing children (Hourcade et al., 2012), or between pairs of users where one single user is diagnosed with ASD and his/her pair was a typically developing child (Dillon & Underwood, 2012; Sharma et al., 2016), a child with another kind of impairment (Keskinen et al., 2012; Marco et al., 2013), or an adult or therapist (Holt & Yuill, 2017; Villafuerte et al., 2012). In most other studies, the collaborative interaction happened among two individuals with ASD (Battocchi et al., 2009; Ben-Sasson et al., 2013; Boyd et al., 2015; Gal et al., 2009; Giusti et al., 2011; Hourcade et al., 2013; Ribeiro et al., 2014; Roldan-Alvarez et al., 2014; Silva et al., 2015, 2014; Silva-Calpa et al., 2018; Tang et al., 2017; Weiss et al., 2011; Winoto et al., 2016), three (Bauminger-Zviely et al., 2013; Farr et al., 2010), or four (Piper et al., 2006).

We observed that, among the systems found, the *Reactable* (Villafuerte et al., 2012) and *SymbolChat* (Keskinen et al., 2012) collaborative games were not specifically designed for individuals with ASD, but they were evaluated with individuals with this condition. For instance, *Reactable* (Villafuerte et al., 2012) was first designed for and tested with typically developing individuals, and only afterward tested in users with ASD. It obtained favorable results, though it relied greatly on the therapist's supervision and personalized assistance. SymbolChat (Keskinen et al., 2012) was designed for individuals with general cognitive impairments, but its evaluation includes one (1) 22-year-old ASD user with

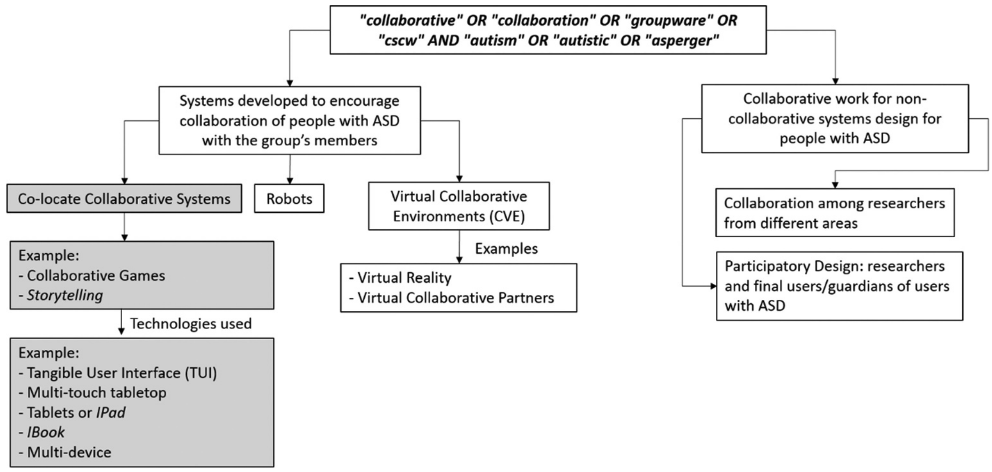

Figure 1. Overview of types of studies retrieved using the search string. Our review includes studies involving co-located collaborative systems in shared workspaces using different technologies (shaded gray).

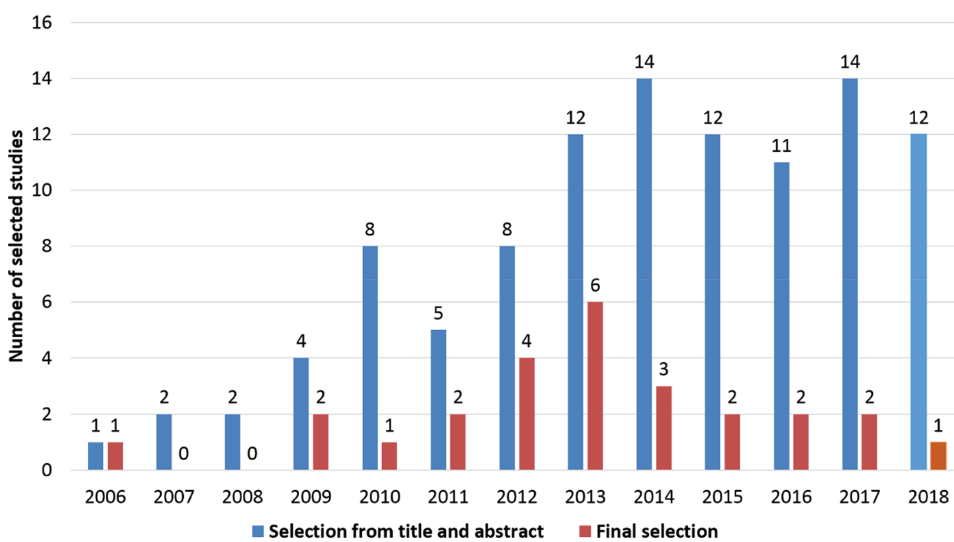

Figure 2. Selected articles according to publication year (total 26).

substantial impairment. Unfortunately, the study does not describe the specific results for this particular user. Tables 4-6 show the description of the systems found.

We analyzed in detail the selected papers to gather information to answer the research questions raised in this review. As opposed to different surveys of systems developed for individuals with ASD that show the contributions to social and communication skills [5]-[9], [47], our survey is focused on identifying the characteristics of collaborative systems not only to motivate the users' abilities but to support collaborative activities and teamwork.

We identify specific characteristics that the collaborative systems (games and applications) proposed in the studies possess both to encourage the collaborative work of individuals with ASD interacting with others and to support the task-awareness and other-awareness in the shared environment. These characteristics are described in the following subsections:

4.1. Strategies employed in the co-located collaborative systems

We denominated "collaborative strategies" to the restrictions, cooperative gestures, or actions required in the systems to encourage the collaborative tasks among both users with ASD and their partners. The collaborative strategies were categorized as follows: (1) strategies that indirectly enforce collaboration, (2) strategies that stimulate collaboration without enforcing, and (3) strategies that allow a free collaboration (Table 7).

4.1.1. Strategies to "enforce" collaboration

Most of the studies found included collaborative systems using rules or restrictions on the interface elements, offering implicit suggestions on how to act, as a mechanism to indirectly foster user collaboration. We categorized these types of restrictions into six strategies that we named: *Taking Turns, Simultaneous*

Table 3. Co-located collaborative systems according to target-users' level of ASD in selected studies.

Collaborative systems proposed in the studies		Severity level ASD of users assessed	Chronological age of the users with ASD (years)	Amount of users with ASD
Zody Game (Boyd et al., 2015)	Treasure Chase Dragon Blast Garden Maze Talk it Over	Moderate social skills deficits (Unspecified ASD level)	8 to 11	8
Reactable (Villafuerte et al., 2012)		Non-verbal (Unspecified ASD level)	5 to 11	6
		Different degree in language skills (Unspecified ASD level)		3
Tablets for Two (Holt & Yuill, 2017)		Severe learning disability (Unspecified ASD level)	5 to 12	8
ToM activity (Roldan-Alvarez et al., 2014)		Unspecified ASD level	9 to 19	8
I Can Tell (Wadhwa & Jianxiong, 2013)		Unspecified ASD level		No tests
Making a Cake (Marco et al., 2013)		Unspecified ASD level	8	1
ComFim (Ribeiro et al., 2014)		Unspecified ASD level	5 and 11	4
Collaborative Puzzle Game (Battocchi et al., 2009)		Unspecified ASD level	13.53 (mean age)	16
Set of activities: *Music Authoring, Drawing*, and *Untangle* (Hourcade et al., 2012)		Asperger syndrome	13 and 14	2
SIDES (Piper et al., 2006)		Asperger syndrome	12.6 (mean age)	3
		Asperger syndrome	12.8(mean age)	2
		Asperger syndrome and attention deficit		1
Invasion of the Wrong Planet (Marwecki et al., 2013)		Asperger syndrome and HFA	8 to 12	No tests
Set of activities: *Music Authoring, Drawing*, and *Untangle* (Hourcade et al., 2013)		HFA	10 to 14	8
TabletG and *TabletopG* (Winoto et al., 2016)		HFA	5, 5, 7, and 9	4
Bubble Dialogue (Dillon & Underwood, 2012)		HFA	8.96 (mean age)	10
Join-In Suite (Giusti et al., 2011)	*Apple Orchard* *Save de Alien* *Bridge*	HFA	9 to 12	8
Join-In Suite (Weiss et al., 2011)		HFA	9 to 13	8
StoryTable (Gal et al., 2009)		HFA	8 to 10	6
No-problem (Bauminger-Zviely et al., 2013)		HFA	9.83(mean age)	14
		HFA		8
Collaborative Puzzle Game (Ben-Sasson et al., 2013)		HFA	8 to 11	12
TabletopG v2 (Tang et al., 2017)		HFA	10	1
		HFA and hyperactivity disorder	8	1
		ASD with severe cognitive impairment	9	1
Balloons (Sharma et al., 2016)		ASD with moderate and severe cognitive impairment	-	10
Augmented Knights Castle (AKC) (Farr et al., 2010)		Moderate to severe autism	11.2 (mean age)	12
PAR Game (Silva et al., 2015, Silva et al., 2014)		Level 3 ASD	10 to 17	5
SymbolChat (Keskinen et al., 2012)		Level 3 ASD	22	1
CoASD Game (Silva-Calpa et al., 2018)		Level 3 ASD (one user is also deaf and another has Hyperactivity disorder)	5 to 14	7

Table 4. Description of the collaborative systems aimed at users without specification of level ASD.

Zody Game (Boyd et al., 2015). This game contains four mini-games for two children using a single iPad. In the main scenario, a player's character carries the other player's character, avoiding dangers cast by groundhogs, while the second character throws fruits at the groundhogs. 1) Treasure Chase: the users must simultaneously press their fingerprints on the screen to excavate and find the buried treasure. 2) Dragon Blast: Two players, each on one side of the tablet, throw ice balls to break the walls surrounding a dragon that spits fireballs. 3) Garden Maze: Each player controls a character in a labyrinth moving toward only two directions: The collaboration between the players allows moving the character in the labyrinth's four directions. 4) Talk it Over: The dragon has a thorn in its foot. The players get to choose the characters and particular strategies (actions, reasoning, and empathy) to better persuade the dragon to remove the thorn.

Reactable (Villafuerte et al., 2012). This application is a musical TUI where one child and his therapist collaboratively create complex musical pieces when interacting over TUI objects grouped into three categories: generators, sound effects (audio filters), controllers, and global objects.

Tablets for Two (Holt & Yuill, 2017). One child with an adult or with an ASD peer interacts simultaneously on identical tasks present in two tablets (each user interact with their tablet). Five different pictures are randomly present. Users must put their picture on a sequencing strip. The pictures must be placed in corresponding positions on each tablet. The game state is correct when pictures are in 'matching' positions on both tablets.

ToM activity (Roldan-Alvarez et al., 2014). This application consists of taking turns in pairs of children to perform individual activities on a multi-touch tabletop. The activity entails choosing the correct answer among several options represented by images and texts, for questions on facial expression recognition or daily life situations.

I Can Tell (Wadhwa & Jianxiong, 2013) is a story-telling app for iPad. It allows the collaboration among children and their parents or guardians to build a story using everyday pictures available in sidebars on both sides of the screen. That distribution of the pictures allows children and their parents to interact on the interface at the same time. The actions performed to build the story can be recorded (the parents can add audio to the story), saved and played back when need. The authors (Wadhwa & Jianxiong, 2013) suggest that playback of the stories can contribute to developing children' language skills. However, this study does not report any evaluation with children.

Making a Cake (Marco et al., 2013). This game consists of two children (a boy on ASD and a boy with attention deficit) collaborating with real toys (animals) on a Tangible User Interface (TUI) to help to a virtual tutor (a farmer) make a cake, giving the ingredients required (strawberries, eggs, and milk). The farmer asks for each ingredient, giving instructions about how the action must be performed. Each action on an object results in a special effect which appears on the game.

ComFim (Ribeiro et al., 2014). Two children using two independent tablets, share elements to accomplish tasks on a farm. A virtual tutor acts as a mediator who provides situations to users solve together. The tutor provides the instructions and the two users interact giving and receiving the necessary elements (images) to solve the task.

Collaborative Puzzle Game (Battocchi et al., 2009), (Ben-Sasson et al., 2013). As in a puzzle game traditional, it consists of assembling a picture from pieces that varied between 4 and 16. The pieces are digital objects available on a large horizontal screen. In the study of Battocchi et al. (Battocchi et al., 2009), two users on ASD must move each puzzle piece together until the picture is assembled. The study of Ben-Sasson et al. (Ben-Sasson et al., 2013) evaluated two versions of the game with users with HFA. In the first version, both users are free to move the pieces, and in the other version, users must touch and release together each puzzle piece.

Table 5. Description of the collaborative systems aimed at users with HFA and/or Asperger syndrome.

Set of activities (Hourcade et al., 2012, Hourcade et al., 2013). The authors proposed three collaborative applications named: Music Authoring, Drawing, and Untangle for interaction among groups of 2 to 6 children. In ***Music Authoring,*** children sit around a multi-touch table to create musical notes collaboratively by taking turns so they can create together a musical composition. ***Drawing*** is a storytelling activity where children stand around a multi-touch table to create and tell stories using a tablet to draw them. One child draws the beginning of a story and then passes the tablet to the next child to draw his/her part of the story and so forth. ***Untangle*** is a type of puzzle game in which the children interact together using a multi-touch shared tablet to move circles that are connected by lines. The aim is to move the circles in a way that no line gets overlapped when solving the puzzle. Hourcade et al. (2012) assessed the games with groups of children both typically developing and diagnosed with Asperger syndrome. Hourcade et al. (2013) assessed the three games with pairs of children with HFA.

SIDES (Piper et al., 2006). A puzzle game that requires four users with Asperger syndrome collaborating to build a path to allow a frog journey along the path and achieve insects. Each user has square tiles with different arrows (e.g., pointing right, around-the-corner, etc.) to build the path by taking turns. No user has all arrow types which encourages them to work together building an optimal path to win more insects and thus more points. Users must agree on the path that collects more insects.

Invasion of the Wrong Planet (Marwecki et al., 2013). This game consists of free collaboration among users (children with HFA or Asperger syndrome) on a multi-touch tabletop to eliminate alien ships together. One single user can eliminate an alien ship, but users get a higher score as they collaborate. The authors do not present an evaluation of this collaborative game.

TabletG and TabletopG (Winoto et al., 2016). The authors proposed the design and test pilot of a collaborative puzzle game in two versions: a tablet (*TabletG*) and a tabletop version (*TabletopG*) for interaction between two co-located children with HFA. This game uses the Active Sharing Pattern proposed by (Silva et al., 2015), which requires two users to share resources, each user receives, sends, and receive help from the other about how to collaborative while working on their workspace. The authors proposed in (Tang et al., 2017) a new version of the game for tabletop (*TabletopG v2*). This version has the same characteristics as the previous version, but it includes a module to assess the reciprocity of players. The authors evaluated this version with both HFA and LFA children.

Bubble Dialogue (Dillon & Underwood, 2012). This application consists of two users (one child with HFA and one typically developing child) building stories through a single iBook laptop computer. Provided to users is two-story scenarios (one reality-based story and another fantasy-based story) in which each user is represented by a different character to identify the creation of the dialogue among them. Users write parts of the narrative indicating by specific bubbles either a speech or a thought.

Join-In Suite (Giusti et al., 2011), (Weiss et al., 2011). It has three games for two children with HFA interacting on a DiamondTouch Tabletop: 1) *Apple orchard*: Two users must move a basket together to grab the falling apples, encouraging joint performance between users. 2) *Save the alien*: the children must collect stars to refuel an alien starship; one child makes the stars fall down, while the other moves a boat to catch them. 3) *Bridge*: the children must repair a broken bridge by interacting, each at one side of a table. They collaborate as they assemble the bridge with their pieces or asking for their partner's pieces when needed.

StoryTable (Gal et al., 2009). This game consists of a storytelling activity. Two users with HFA must create a story in common by interacting together on ladybugs objects crawling around the interface of a tabletop surface. Interaction with one of these ladybugs gives access to its contents. Users select the background on which the story will be set through collaborative interaction (the background is carried on the largest ladybug). Other ladybugs carry the elements that can be dragged into the selected background.

No-problem (Bauminger-Zviely et al., 2013). Through a desktop computer with multiple mice, three children with HFA create social conversations related to solving an interpersonal problem occurring in one of the three social environments – school, after school activities, and at home -. Users compose thought vignettes on the computer screen, which are possible solutions to a given problem. Users can create and videotape the conversations at each conversation stage (start a conversation, maintain it, and end it).

Table 6. Description of the collaborative systems aimed at users with Level 3 ASD and cognitive impairment.

Balloons (Sharma et al., 2016). This game requires two users to select together a virtual balloon out of the three possible options to win a rainbow, encouraging joint attention between users with Moderate to severe cognitive impairment and typically developed children. The Balloons application uses a Microsoft Kinect connected to a computer and a display.

AKC (Farr et al., 2010). This TUI application is composed of three base units (a castle, a dragon tower, and a magic pond area) that identify the location of individual objects (toys) by using radio frequency identification (RFID). In one version of AKC, each user from a group of 3 users (children with moderate and severe autism) places specific objects into one of the three bases, and according to the object's position, prerecorded sounds are played. The second version is configurable; here, users also could put the object in a "magic box" to speak and program each object's speech. Users can play freely on AKC, putting objects and recording sounds in a period of twenty minutes.

PAR Game (Silva et al., 2015, Silva et al., 2014). This game has three levels of collaboration difficulty, in which two users with Level 3 ASD around a multi-touch tabletop gradually share resources, information, and simultaneously interact to obtain items of soccer players' uniforms (shirt, shorts, and sneakers) in order the dress eleven characters of a team. Each user has a different role. One of the users sends the items, and his/her partner receives them. The two users take the role of dress each character of the team.

SymbolChat (Keskinen et al., 2012). This application consists of a chat that uses the Picture Exchange Communication System (PECS) (simple images specifically designed for individuals with language impairments) instead of text to convey messages. Two or three users are sharing information through a touchscreen tablet computer. The authors tested *SymbolChat* with individuals with different disabilities, among them, only one individual with ASD.

CoASD Game (Silva-Calpa et al., 2018). This game requires two users around a multi-touch tabletop to drive a car down a road overcoming together different obstacles. Each user has a different role. One of the users takes the car-driver role and his partner is the driver's assistant. Similar to *PAR Game, CoASD Game* has three levels of collaboration difficulty to overcome the obstacles. In the first phase, when one of the users reaches an obstacle with the car, his partner must send him the help respective. In the second phase, the user in the role of a car driver must ask for help; then his partner sends it. The third phase includes additionally some tasks that require simultaneous interaction of both users. The *CoASD Game* provides to users with different interface elements to gradually provide collaboration support.

Table 7. Strategies used in collaborative systems to encourage collaboration among users.

Collaboration Strategy		Description
Strategies to "enforce" collaboration	**Taking Turns**	Requires participants taking turns to accomplish tasks and achieve a common goal.
	Simultaneous Interaction	It consists of enforcing the simultaneous interaction of two or more users on the same or different elements on the shared interface. Users should interact together to touch or move the element(s) in the interface, achieving a common goal.
	Different Role	It consists of designate different roles to users sharing resources and achieve a common goal.
	Exchange of Information	It consists of active sharing to exchange information among users. This exchange may take place through several interface elements or using images to exchange messages.
	Negotiation	It consists of designate different elements that are owned by each user. Users should coordinate the actions to share their elements and achieve a common goal.
	Symmetrical Actions (Morris et al., 2006)	It consists of designate the same action by all users in the game, but each using a different controller (Boyd et al., 2015).
Stimulating Collaboration		It consists of giving rewards when all users perform the activity collaboratively. The collaboration is not mandatory, a single user can perform a task, but the more multiple users collaborate, the more they will see special effects appear on the game and obtain a higher score.
Free Collaboration		It consists of allowing free interaction with the elements in the shared space to achieve a common goal.

Interaction, Symmetrical Actions, Different Role, Exchange of Information, and *Negotiation*, as shown in Table 7.

Some studies mention the inclusion of specific strategies – for example, the *Simultaneous Interaction, Different Role*, and *Negotiation* strategies were used in (Giusti et al., 2011), (Weiss et al., 2011), (Silva et al., 2015, 2014), where they are called *Collaboration Patterns*. The *Simultaneous Interaction* strategy adopted the definition of "Enforced Collaboration Paradigm" used in (Battocchi et al., 2009; Ben-Sasson et al., 2013; Gal et al., 2009). The *Symmetrical Actions* and *Stimulating Collaboration* strategies adopted the description of cooperative gestures set proposed by (Morris et al., 2006), where they are called "Symmetry" and "Additivity" gestures, respectively.

Table 8 shows the strategies used in each collaborative system. The contributions of these strategies reported by some of the studies are described below.

4.1.1.1. Taking turns. This strategy consists of two or more participants taking turns to accomplish specific tasks on a shared interface. It is used in eight studies intended for users with unspecified ASD severity, HFA, and Asperger's Syndrome (Table 8). The authors reported that *Taking Turns* helped users to be more aware of the partners' actions throughout the test sessions (Roldan-Alvarez et al., 2014; Villafuerte et al., 2012), resulting in positive social behaviors such as encouraging the other user to share emotions, show interest, and propose actions during the games (Gal et al., 2009). Piper et al. (2006) highlighted that this strategy encouraged children with Asperger's Syndrome to communicate with their peers and pay attention when it is their turn to participate in the game.

Studies by Hourcade et al. (2012) and Dillon and Underwood (2012) reported that the *Taking Turns* strategy helped users to comprehend their own interests as well as their partners' interests, thereby allowing them to contribute to the collaborative activity. Hourcade et al. (2012) reported that users enjoyed the activity and gave feedback about their interaction in the games, but the users also proposed to add colors to and more musical instruments to the *Drawing* and *Music Authoring* applications, respectively.

The studies above suggest that the *Taking Turns* strategy showed great potential for improving social behavior, acquiring certain language abilities, and even minimizing repetitive behaviors which are typical for individuals with ASD. However, Villafuerte et al. (2012) suggest that for the exchange by turn-taking to happen, it is necessary that participants infer intentions and anticipate others' behavior patterns. Thus, this strategy could be not suitable for individuals with more severe impairments in social-awareness.

Table 8. Strategies used by each collaborative system in the selected studies.

Severity level ASD of users assessed	Collaborative systems proposed in the studies		Users interacting together and device(s) used	Strategies used: Taking Turns	Simultaneous interaction on the same object	Simultaneous interaction on different objects	Exchange of Information	Different Role	Negotiation	Symmetrical Actions	Stimulating Collaboration	Free Collaboration
Unspecified ASD level	*Zody Game* (Boyd et al., 2015)	Treasure Chase	Two ASD children interacting with a single iPad			✓				✓		
		Dragon Blast						✓		✓		
		Garden Maze		✓						✓		
		Talk it Over						✓	✓			
	Reactable (Villafuerte et al., 2012)		One ASD child with his therapist interacting in a TUI and circular tabletop	✓								✓
	Tablets for Two (Holt & Yuill, 2017)		One user with ASD with an adult or an ASD peer — Single tablet									✓
			Dual tablets							✓		
	ToM activity (Roldan-Alvarez et al., 2014)		Two children with ASD around a multitouch Tabletop	✓								
	Making a Cake (Marco et al., 2013)		One ASD child with the child with deficit attention interacting on a NikVision Tabletop (TUI multi-device: table surface and a monitor)									✓
	ComFim (Ribeiro et al., 2014)		Two children with ASD interacting on tablets. They observe their interaction in a shared TV				✓	✓				
	Collaborative Puzzle Game (Battocchi et al., 2009)		Two children with ASD interacting around a DiamondTouch Tabletop		✓							
Asperger syndrome	Set of activities (Hourcade et al., 2012, Hourcade et al., 2013)	*Music authoring*	Groups of 2 to 6 children both typically developing and diagnosed with ASD interacting on a Dell XT2 multitouch Tablet (12′1′)	✓								
		Drawing		✓								
		Untangle				✓						
	SIDES (Piper et al., 2006)		Four children with ASD interacting on a DiamondTouch Tabletop									✓
Asperger and HFA	*Invasion of the Wrong Planet* (Marwecki et al., 2013)		It proposes using a Samsung SUR40 with Microsoft PixelSense (no tests)	✓					✓		✓	

(*Continued*)

Table 8. (Continued).

Severity level ASD of users assessed	Collaborative systems proposed in the studies	Users interacting together and device(s) used	Strategies used								
			Taking Turns	Simultaneous interaction on the same object	Simultaneous interaction on different objects	Exchange of Information	Different Role	Negotiation	Symmetrical Actions	Stimulating Collaboration	Free Collaboration
HFA	*TabletG and TabletopG* (Winoto et al., 2016) *TabletopG v2* (for HFA and LFA children) (Tang et al., 2017)	Two children with ASD interacting in a large-screen tabletop (Lenovo Horizon 27″) but each child has an individual workspace.				✓					
	Bubble Dialogue (Dillon & Underwood, 2012)	One child with ASD and one typically developing child using an Apple Macintosh iBook laptop computer	✓								
	Join-In Suite (Giusti et al., 2011) *Apple Orchard*	Two children with ASD and a therapist acting as a moderator interacting around a DiamondTouch Tabletop		✓						✓	
	Save de Alien Bridge						✓	✓			
	StoryTable (Gal et al., 2009)	Two children with ASD interacting around a DiamondTouch Tabletop	✓	✓							
	Collaborative Puzzle Game (Ben-Sasson et al., 2013)	Two children with ASD interacting around a DiamondTouch Tabletop		✓							✓
ASD and cognitive impairment	*Ballons* (Sharma et al., 2016)	One child with moderate to severe cognitive impairment and one typically developed using a Microsoft Kinect connected to a computer and a shared display									✓
	Augmented Knights Castle (AKC)	Groups of three children interacting on a TUI with augmenting toys									✓
	PAR Game (Silva et al., 2014), (Silva et al., 2015)	Two children with ASD interacting around a multitouch Tabletop			✓	✓	✓				✓
	SymbolChat (Keskinen et al., 2012)	Two or three users (one single user with ASD) interacting on a touchscreen tablet computer				✓					
CoASD Game (Silva-Calpa et al., 2018)		Two children with ASD interacting around a multitouch Tabletop		✓	✓	✓					

4.1.1.2. Simultaneous interaction. This strategy requires two or more users interacting simultaneously to accomplish specific tasks on the same or different elements of the shared interface. Three of the retrieved studies reported the contribution of this strategy for users, as follows.

Battocchi et al. (2009) revealed that the *Simultaneous Interaction* strategy improves behavioral therapies that involve interaction with other people and social contact, and reinforces the need for collaboration. Hourcade et al. (2012) stressed that *Simultaneous Interaction* encourages communication, cooperation, and coordination, motivating children to make suggestions about movements and facilitating interactions with their game partners. Hourcade et al. (2012) mentioned that users of the *Untangle* application enjoyed collaborating with their partners to solve the game. However, Battocchi et al. (2009) mentioned that, while playing the *Collaborative Puzzle Game*, users showed difficulty in performing coordination activities during collaboration. Hence, they suggest that users with more severe levels of ASD require help from therapists to get involved in the game (Battocchi et al., 2009).

Ben-Sasson et al. (2013) also tested two versions of the *Collaborative Puzzle Game* with dyads of users with HFA. One version includes the *Simultaneous Interaction* strategy, and a second version includes an unforced collaboration strategy (*Free Collaboration*). The authors identified that the enforced strategy promoted more positive social behaviors among users than in the tests that did not force their joint interaction, although users with a more severe lack of social-communication skills presented less positive behaviors. The authors (Ben-Sasson et al., 2013) highlighted that the *Simultaneous Interaction* strategy requires the practice of social skills and collaboration, but also mentioned that being "force[d]" to practice these skills can increase the frustration in the users. They mentioned that some children interacting with the game in the enforced strategy felt overwhelmed because they could not intuitively win.

It is worth noting that enforced simultaneous interaction on a same interface element also depends on the kind of devices used. For example, systems implemented for DiamondTouch Tabletop (Dietz & Leigh, 2001) can enforce more interaction and collaboration from users because this device has recognizes the parts of its surface that are being touched. Thus, the system recognizes the actions of each user on the tabletop surface. In contrast, systems that utilize smaller form factors, such as iPads or other tablets, require an external mediator (i.e., a therapist) to prevent users from interfering with each other's tasks. In addition, these types of systems do not support touch identification of multiple users. This means that one user could perform all the tasks by themselves, detracting from the collaboration. However, Boyd et al. (2015), suggest that these small devices have the advantage of closer proximity with the collaborators, which in itself can be a great contribution to the development of social skills in individuals with ASD.

4.1.1.3. Symmetrical actions. Using this strategy, each collaborator should perform the same actions but using a different controller. Symmentrical Actions Strategy was used in a recent study by Holt and Yuill (2017). The authors present two versions of the *Tablets for Two* application, one version using two tablets and a second version using one single tablet. For the first version, the authors used the Separate Control of Shared Space (SCoSS) framework. This framework supports collaboration in joint activities through "*separate control over an identical version of the task for each child, within their own private screen space, that is visible to both participants*" (Kerawalla et al., 2008). Thus, each user has control over their own tablet, but the two tablets are arranged side-by-side on stands creating a shareable environment and allowing the other's task awareness (Holt & Yuill, 2017). The single tablet version allowed free collaboration, through which users freely moved pictures on the sequencing strip. The study suggests that the dual tablets version was more effective at facilitating active other-awareness behaviors of the user with ASD than the single tablet version. Pairs of users with ASD interacting with two tablets showed more approach to the task and greater awareness of the other's task than using a single tablet. However, users with ASD had more other-awareness when interacting with an adult partner.

4.1.1.4. Exchange of information. This strategy requires participants' exchanging of information through interface elements. The *Exchange of Information* strategy is used in four of the retrieved studies. In *SymbolChat* (Keskinen et al., 2012) and *ComFim* (Ribeiro et al., 2014), users exchange messages with images. In the *TabletG, TabletopG* (Winoto et al., 2016), *and TabletopG v2* (Tang et al., 2017) applications, two users solve a collaborative puzzle game by exchanging messages.

The authors of *SymbolChat* (Keskinen et al., 2012) revealed that a user with high cognitive impairment expressed, through a graphics scale with a system of emoticons called *Smileyometer*, that the communication was extremely difficult even though it was fast and fun. The average user sent only three PEC figures per message. The authors argued that some users who ignored their partner's message may need therapist support. Ribeiro et al. (2014) point out that the *ComFim* game generated communicative actions among users, and that they gradually started to learn the roles involved in the game.

The authors of the *TabletG* and *TabletopG* applications (Winoto et al., 2016) revealed that users showed great enthusiasm in the games, especially *TabletopG*. However, the study did not show specific results regarding the collaboration strategy used or skills encouraged in the users through the games. The authors mentioned that in *TabletopG v2*, the boy with high cognitive impairment offered assistance less proactively in the game than the HFA children. Although both children were able to initialize bids for his/her partner's joint attention, that action was merely to request something and not to actively share (Tang et al., 2017).

4.1.1.5. Different role to share resources and negotiation. In the *Different Role* Strategy, each user has a different role in the game to achieve a common goal. In the *Negotiation* Strategy, each user has control over several elements to negotiate with their partners and achieve a common goal. In the retrieved studies, the *Different Role* and *Negotiation* strategies were used together with other strategies.

As shown in Table 8, the *Zody Game* (Boyd et al., 2015), the *Join-In Suite* (Giusti et al., 2011), (Weiss et al., 2011), the *PAR Game* (Silva et al., 2015, 2014), and the *CoASD Game*

(Silva-Calpa et al., 2018) contain three or more collaborative strategies together. The *Join-In Suite* is designed for users with HFA, the *PAR Game*, and the *CoASD Game* for users with Level 3 ASD. In both cases, the results obtained from using multiple strategies were promising. However, these studies do not report the contribution from each strategy individually, but from all strategies together.

The mini-games from *Zody Game* (Boyd et al., 2015) include tasks that assign a *Different Role* to each user and require **turn-taking, negotiation**, and **simultaneous interaction** of pairs of users (unspecified ASD level) to perform *Symmetrical Actions* in the same iPad device. The authors evidenced that when users became engaged in an interaction with another, they demonstrated feelings of being part of a group and exhibited empathy during others' winnings and losings. The authors mentioned that on some occasions, the size of the iPad led to a single user playing both their role and the partner's role, causing difficulty in coordinating their actions. Thus, they note that even though users can collaborate with one another, it is important to include ways of imposing roles for each player, and teaching them the importance of dynamically negotiating roles with game partners.

The *Join-In Suite* (Giusti et al., 2011; Weiss et al., 2011) used one or two strategies for each one of their three games: In *Save the Alie,n* users have **different roles** to collect, start, and refuel an alien starship. In *Bridge*, users **negotiate** to assemble a bridge with their own pieces and pieces that belong to the other user. In the *Apple Orchard game*, the *Simultaneous Interaction* strategy is utilized when users must move a basket together to receive falling apples. The authors (Giusti et al., 2011) highlight that users were interested in performing the tasks in all three games, also noting therapists' feedback that the Join-In Suite is intuitive and easy to use. They concluded that the users learned the importance of collaboration as they advanced in the game (Giusti et al., 2011) by properly applying collaboration strategies (Weiss et al., 2011). They highlighted regulations for user collaboration that contributed to the children learning through performance of the activity according to collaboration strategies, and encouraged their pairs to interact and complete the games.

Studies including the *PAR Game* (Silva et al., 2014, 2015) and the *CoASD Game* (Silva-Calpa et al., 2018) used strategies gradually in the three phases of the games. The first phase of each game includes the *Different Role* strategy, the second phase includes the *Exchange of Information* strategy, and the third phase includes the *Simultaneous Interaction* strategy in addition to the previous strategies. The authors (Silva et al., 2014, 2015; Silva-Calpa et al., 2018) suggest that each one of the restrictive strategies increased the collaboration difficulty and, thus, contribute to gradual encouragement of collaboration among users. Each subsequent phase of the game generated a greater need for collaboration in the two games. This increased user motivation to perform the tasks, facilitating their verbal and non-verbal expressions to interact with their partners and to coordinate actions in the shared workspace.

4.1.2. Strategy to stimulate collaboration

Contrary to the above strategies, two of the retrieved studies utilized one strategy that incentivized collaboration without enforcing it. This strategy consists of non-mandatory mechanisms that motivate users to work collaboratively in the workspace, such as those used in the *Invasion of the Wrong Planet* (Marwecki et al., 2013) and *Balloons* (Sharma et al., 2016) applications.

In *Invasion of the Wrong Planet* (Marwecki et al., 2013), users get higher scores when eliminating alien ships together with their partners. Although this application was not evaluating the users, the authors express the importance of encouraging collaboration little by little, without enforcing it. The authors suggest that this approach can be successful because the difficulty of the game does not result from the cognitive resolution of a task, but from achieving social interaction and communication every time the players decide to collaborate.

In the *Balloons* application (Sharma et al., 2016), if two users select the same balloon on a screen within three seconds, a rainbow will grow as their reward. The authors observed that *Simultaneous Interaction* promoted joint attention between users, but did not present information about the provided rewards. However, the time allowed (three seconds) was too quick for some users, causing disinterest. A therapist in the study mentioned, "*a system like Balloons allows more students to be engaged while viewing the activity on the screen together*." (Sharma et al., 2016).

4.1.3. Strategies to free collaboration

Some of the collaborative systems in the studies offer an environment that allows free interaction among users, without any restriction or incentive. Some studies included strategies to free collaboration together with restrictive strategies.

Piper et al. (2006) tested two versions of the *SIDES* application with children with Asperger's Syndrome. One version includes restrictive strategies, and another version allows **free collaboration**. The authors reported that the users mentioned the version with free collaboration was easiest to play, and allowed them to work together better than in the version with restrictions. Moreover, some users mentioned the version without rules (using *Free Collaboration* strategy) allowed a more relaxed interaction than the version that enforced collaboration. Similarly, in the study by Ben-Sasson et al. (2013), the authors identified that the free collaboration mode of the *Collaborative Puzzle Game* is less challenging than using the enforced strategy because users can complete the puzzle without restrictions, although some users tend to complete the task individually.

The *PAR Game* proposed by Silva et al. (2014, 2015) includes a section in the game for users to accomplish some tasks without restrictions (*Free Collaboration*). The authors (Silva et al., 2014) observed that collaborative learning was evident when users dress soccer players in the game. They highlighted that in this non-mandatory part of the game, users gradually learn to collaborate, using new ways to perform the task together, such as taking turns to dress the soccer player in the game, or helping when required while one partner dresses the soccer player.

Two of the analyzed studies proposed TUI games and used the *Free Collaboration* strategy as a single strategy to encourage collaboration (Farr et al., 2010; Marco et al., 2013). In these games, the users can play freely, manipulating TUI objects.

In the *Making a Cake* application, Marco et al. (2013) observed that each child explored the shared environment, interacting with the toys while waiting for their partner to perform the task required by a virtual tutor. However, they mentioned that tested children needed the support of their teachers to begin playing and to keep up interaction required to continue the game. It should be noted that these results refer to all children tested who had different special needs, though the study does not specifically mention the results obtained from the single ASD user tested.

In the AKC version game that allows children to put freely toys in a shared "magic box" to speak and program each toy's speech, the authors (Farr et al., 2010) report that there was more collaborative and parallel play than in the non-configurable version. Toys' individual content increased the interest of users with regards to both the system and the recordings made for others. However, that feature also led the users to want to switch all of the digital aspects of toys. The study does not report specific results about collaborative work performed by users; however, the authors note the benefits of configurable tangibles for children with ASD, which enables more opportunitiy for interaction among them.

4.1.4. Summary of findings

Most of the analyzed studies used strategies in the collaborative systems to "enforce" collaboration among users and strategies to free collaboration. Two studies used strategies to stimulate collaboration; however, they did not present results about the contributions of these strategies for users. Meanwhile, we also identified two studies (Bauminger-Zviely et al., 2013; Wadhwa & Jianxiong, 2013) that do not mention using any strategy to encourage collaboration.

The analyzed studies reported that the collaborative systems assessed contributed to promoting different collaborative skills such as cooperation, communication, coordination, joint attention, empathy, compromise, negotiation, social interaction, sharing, and creativity. Although promising results were shown, most of these studies were designed and tested for users with less severe levels of ASD or without specification of their ASD level of impairment. We highlighted the following points:

- When a computational application gradually encourages collaboration through different levels of collaborative difficulty; i.e., using gradually different strategies such as in the studies by Ribeiro et al. (2014), Silva et al. (2015), and Silva-Calpa et al. (2018), contribute positively for users understand the collaborative tasks. This approach can be favorable for users with more severe ASD who have difficulties interacting under the *Simultaneous Interaction* and the *Exchange of Information* strategies.
- Collaborative systems using both free collaborative and restrictive strategies present positive and negative results. Systems using the *Free Collaboration* strategy can be easiest to play, but users tend to perform the tasks individually. Systems using restrictive strategies can contribute to positive social behavior and encourage coordination and negotiation, but can become overwhelming for some users.
- There should be provision of diverse activities using different strategies, as each can contribute to learning the importance of collaboration (Boyd et al., 2015; Giusti et al., 2011). However, it is important to use an appropriately sized device to collaborate successfully.
- Both the contribution of the *Taking Turns* and *Simultaneous Interaction* strategies incentivize individuals with ASD the awareness of others and their actions in the shared space. The contribution of *Simultaneous Interaction* strategy is to encourage the social behavioral and language skills of the users.

4.2. Collaboration support mechanisms offered by co-located collaborative systems

The second question raised by this systematic literature review requires searching for collaboration support mechanisms offered to users through collaborative systems found in the literature. Collaboration support mechanisms involve both the strategies mentioned in the previous subsection and the elements available in the shared workspace to be successful.

Among the different revised studies, some described the distinguishable elements offered for users, but only eight of them report some contribution of the collaboration support mechanisms used. These studies were assessed with pairs of users, in some of them a single user was an ASD child (Dillon & Underwood, 2012; Holt & Yuill, 2017; Marco et al., 2013; Sharma et al., 2016; Villafuerte et al., 2012) and in others, the collaborative interaction happens among two users with ASD (Battocchi et al., 2009; Roldan-Alvarez et al., 2014; Silva-Calpa et al., 2018). Among these studies, only two of them (Holt & Yuill, 2017; Silva-Calpa et al., 2018) specifically mention the importance of including aspects to provide awareness support. In the eight studies, support is provided by visual and auditory stimuli, visual and auditory feedback, virtual tutors, 3D animations, characters, or instructions on the screen.

The *Make a Cake* game (Marco et al., 2013) provides support through a virtual tutor, images, sounds, and 3D animations which indicate to users how to perform the tasks and when it is finished. The authors point to the need for providing appropriate feedback in the game as a way to encourage users to continue performing the activities and awarding them when the task is finished. They concluded that the virtual tutor offered fundamental support for task completion but had a negative impact on co-located gaming rates.

In the Balloons application (Sharma et al., 2016) varied visual and auditory feedback is included because of the different sensitivity and capability levels of the individual with ASD. The authors include colored balloons with smooth movements to draw the attention of the participants, as well as rewards such as applause or music to encourage their simultaneous interaction in the application. They note that, though the users generally were more attentive to visual stimuli than auditory stimuli, auditory feedback used to show a victory (applause) encouraged the performance of users.

The musical characteristics of taking turns in the *Reactable* game (Villafuerte et al., 2012) allowed each sound created by the therapist to call the attention of the user to that action, thus allowing awareness of the other's actions in the shared space that is reflected in their (user) own workspace. *Reactable* also provides pleasant sounds to support the users whose attention is lacking, but the study does not provide findings indicating the the contribution of sounds to the task's completion.

We highlight the *BubbleDialogue* application (Dillon & Underwood, 2012) which presents mechanisms to assist the partners' awareness support. In the *BubbleDialogue*, users identify the participants of the activity through the characters that appear on the screen with their names and the task they must perform through written instruction on the screen. The authors mentioned that users with ASD in their pairs created coherent narratives according to the story. They made some errors using thought bubbles in the dialogue, but they also demonstrated their imaginative capacity. The authors highlighted a particular situation: "*the child with autism makes reference to their character possessing psychic powers which enables them to read other people's minds*" (Dillon & Underwood, 2012).

We found a single study (Holt & Yuill, 2017) that aims to facilitate the other-awareness between one user with ASD and his therapist. The authors recommend the use of *Tablets for Two* application and show how both elements in the interface and devices are used to support the collaborative task. This is due to the affordance of "imitation" used by the identical task in the dual tablets for the two users, as specified in the previous subsection. In the application, users can see their partner's ongoing task state. When pictures of the users are put in matching positions on both tablets, the borders around both users' pictures turn green. This means that the action is correct. In the opposite case, the borders around pictures remain uncolored and the application will not generate a new picture to continue the activity. A 'We agree' icon flashes red informing users that they are incorrect (Holt & Yuill, 2017), encouraging them to try again together.

Studies involving pairs of users with ASD also provided support with elements easily recognized by users. A single study (Silva-Calpa et al., 2018) explicitly mentions providing collaboration support through interface elements. Silva-Calpa et al. (2018) explains that "*support is offered on different levels to slowly bring users closer to the knowledge of collaboration*." The first level provided support through a virtual tutor giving short and simple instructions and flashing lights around the current task. Support is increased in the next level, and users are guided through their tasks by parallel visual instructions and highlighted elements. The user is also called by their name and their photograph is shown in the interface. In the next level, support is decreased, with only audio instructions and a visual arrow to indicate the current task. The last level provides the same support that would be offered for typically developing individuals: visual and auditory instructions and feedback. The authors report that these features positively supported users in the performance of required tasks, raising their interest in collaboration and helping them to better understand the necessity of collaboration with others.

In the application by Roldan-Alvarez et al., (2014), visual feedback with sounds indicating the result of each activity is provided; the sounds also indicate the change of turn between users. The study reports that the sounds contributed to both the identification of the person who had the turn and the results of the activity. Battocchi et al. (2009), included animations, and visual and auditory feedback to both make the users' interaction more understandable, and to indicate when they must work together on a puzzle piece in the *Collaborative Puzzle Game*. When a piece is touched by a single user, the piece oscillates, a vibration sound is played, and the movement of the piece is not permitted until another user touches it. The piece can be moved and released only when both users touch it. The authors suggest that the game's feedback contributes to consistent responses to the users' interaction on the interface. They indicated that users with ASD did not show discomfort in response to the sounds provided.

Although in the rest of the studies it is not clear which available mechanisms contributed or not to the collaborative work of users, the following describes the mechanisms identified.

In the *Zody Game* (Boyd et al., 2015) the users can, for example, find out what their tasks are from the controls available – each one of them displaying different colors. At the end of the game, a display of the message "We did it" indicates that they were able to work in a group, providing visual and auditory praises.

ComFim game (Ribeiro et al., 2014) and *SymbolChat* (Keskinen et al., 2012) use the *Picture Exchange Communication System* (PECS) as the primary support tool for the task performance. PECS is a set of simple object representations designed to promote communication of individuals who are language impaired. Among the PECS images included in *ComFim* were eggs, flowers, a stair, and a water pitcher, which aided in the sharing of images and completion of the tasks on a virtual farm. Likewise, in *SymbolChat* (Keskinen et al., 2012) the PECS images are used to both build the messages and provide information about who sent each message. *SymbolChat* (Keskinen et al., 2012) shows photos with the names of the participants and the chat history; next to each chat message is a photo of the participant that sent the message and a PECS image which reads: "he/she said." The authors describe, in general, the benefits of PECS but did not mention whether the use of PECS contributed to the users' collaborative tasks. The authors of *SymbolChat* mentioned that some users ignored the received messages.

Piper and colleagues (Piper et al., 2006) show that the distribution of puzzle pieces in the tabletop surface of the *SIDES* game works as a collaboration support mechanism. The center area of the surface is the group space, and the areas directly in front of each user are for their personal items. Each user has a control panel close to their area with voting buttons to vote on the path being built. All users must unanimously touch these buttons to test the path. This mechanism ensures that no one user has more control over decisions in the game. The personal area also includes a turn-taking button that indicates whether or not it is that user's turn. *SIDES* also did not have a timer or any time limits to prevent users from forgetting to collaborate because they felt rushed.

In Tablet G, TabletopG, and TabletopG v2 (Tang et al., 2017), both the workspace and each puzzle piece have colored borders indicating ownership. Additionally available is a blue button that can be pressed to ask for help. In TabletopG v2, the help button includes the symbol "?" for ASD children that cannot recognize words. In the StoryTable application (Gal et al., 2009), ladybugs are different colors and sizes according to their function. Ladybugs that record audio snippets display a different colored aura according to their child. Each child can record audio snippets in a ladybug, making that ladybug their own. The intention in the StoryTable is that each child can modify his own audio, but both children may agree to interact together on the ladybug to release ownership.

Similarly, in Join-In Suite (Giusti et al., 2011), despite potential for encouraging collaboration and engagement of users with HFA, the authors report that they are remedying some features of the system that teachers and users note as lacking. For example: "*The feedback could have been more interesting, and dynamic. Possibly to have some moving animation at the end*", "*… we* [teachers] *didn't have enough feedback from the screen like someone cheering them* [children]" (Giusti et al., 2011). In the *invasion of the Wrong Planet* (Marwecki et al., 2013) the visual and auditory feedback is provided only when the users reach a high score as a result of their collaboration. The authors suggest that feedback encourages the collaborative behavior among users; however, that fact does not evidence lack of rigorous assessment.

4.3. Requirements found in the literature for the design of co-located collaborative systems

In some of the papers selected for review, we identified different requirements of co-located collaborative systems for individuals in ASD, either related to what the authors used to develop the systems, or what they recommend after the empirical assessment of such systems.

In the studies assessed with users on the different ASD levels (HFA, Asperger Syndrome, Level 3 ASD, ASD and cognitive impairment, and unspecified ASD level), the authors suggest requirements that we categorized as: *customizable, simple, visual*, and *human-mediated*.

4.3.1. Customizable

Applications must offer possibilities to customize the interface, allowing customized text, audio, and animation (Ribeiro et al., 2014) to meet different needs of users with ASD (Wadhwa & Jianxiong, 2013), (Keskinen et al., 2012) due to their hypersensitivity.

4.3.2. Simple

Applications should be easy and intuitive (Chen, 2012; Giusti et al., 2011; Weiss et al., 2011), avoid complex movements (Marwecki et al., 2013) and incorporate socially acceptable gestures (Sharma et al., 2016), thus promoting concentration, comprehension and learning (Ribeiro et al., 2014).

4.3.3. Visual

Applications must offer ample visual content, without interfering with user attention (Hourcade et al., 2012), taking care to exclude distracting interface elements (Roldan-Alvarez et al., 2014). Content should be adapted to the user's characteristics, including real images to help in the identification of real situations (Roldan-Alvarez et al., 2014). If texts are included, they must be easy to read and appear in combination with visual information to promote a user's thorough understanding of the information (Roldan-Alvarez et al., 2014). Using colorful graphics with smooth visual movements captivate the attention of the users for longer periods (Sharma et al., 2016).

4.3.4. Human-mediated

The authors highlight the importance of the children's teachers, parents and/or guardians participation to support the interaction process, as they play a crucial role in guiding and motivating the users. Therefore, a virtual character should not be used as a substitute for these people (Marco et al., 2013). Holt and Yuill (2017) propose "*when using computer technology to support joint activities and collaboration in LDA (*learning-disable autism*) children, such an intervention needs to consider and take advantage of the different strengths of adult and peer partnerships*".

In the studies developed for users with ASD without a specified severity level, the authors forward the following requirements:

4.3.5. Visual and auditory feedback

Providing an appropriate visual and auditory feedback to encourage users to perform the subsequent actions (Marco et al., 2013; Silva et al., 2015), promote reciprocated communication (Keskinen et al., 2012), and support the easy understanding of the interaction (Battocchi et al., 2009). When a task is finished positive reinforcements such as cheers, laughter, dance should be used in addition to spoken words (Marco et al., 2013) presenting success, error or help messages (Silva et al., 2015). Regarding the use of virtual characters for feedback, the characters must be emotive, conveying happiness to indicate positive effects, and sadness to indicate negative effects (Marco et al., 2013).

We recommend applying different types of sounds to give feedback on how users should interact on the interface indicating the effects of actions performed, and presenting success, error, and help messages.

4.3.6. Difficulty levels

Ways of imposing roles on players, besides teaching the importance of dynamically negotiating roles with the partner (Boyd et al., 2015), should be included in the game. The level of difficulty in performing coordinated movements must be suitable to keep users motivated (Boyd et al., 2015).

4.3.7. Awareness support

Holt and Yuill (2017) mention that providing other-awareness support in systems for learning-disabled children facilitates joint attention, as well as communicative behavior. The authors highlight that "*technology alone is not sufficient to facilitate collaborative activity in learning-disabled children with autism: it is the design of the affordances offered by the technology that is critical*". (Holt & Yuill, 2017).

Beyond these requirements, Boyd and collaborators (Boyd et al., 2015) point to a characteristic at the hardware level, suggesting that the size of a system device should be large enough to hinder children from reaching their partner's side of the screen, so as to stop them from performing their partner's task. This aspect could teach the user other collaborative values.

The studies intended for users with Asperger syndrome and HFA mention requirements that we categorized as follows:

4.3.8. Application with the freedom to make mistakes

Applications that do not show any wrong answers or error messages (Hourcade et al., 2012) prevent users from becoming frustrated, or motivated to make the necessary attempts.

4.3.9. Difficulty levels

Having simple interface elements is mandatory since the objective is to help users deal with the complexity of interaction in the real world. If the users initially manage to feel comfortable with the interaction taking place on the application, they can afterward be motivated with more challenging tasks (Hourcade et al., 2012). In order to keep users motivated, the difficulties in the game must change, and the overall time of the game must not exceed ten minutes (Marwecki et al., 2013). Enforcement strategies that allow variations should be included, allowing adjustable and determinate rules and tuning with the appropriate level of support for each group of users (Piper et al., 2006).

Finally, the studies including collaborative systems for users with severe levels on ASD recommend the following requirements:

- Include tasks about decision making to encourage the interaction (Sharma et al., 2016). However, Silva et al. (2015), highlight that specialists in ASD in recommend taking care of the amount of information, restrictions, and support provided to avoid 'excesses'.
- Gradually encourage coordination tasks, mainly for individuals with severe ASD (Silva et al., 2015). Silva-Calpa et al. (2018) suggest including tasks to gradually stimulate every dimension of collaboration: cooperation, communication, coordination.
- Silva-Calpa et al. (2018) suggest offering different levels of support to approximate users to the knowledge of collaboration.
- Sharma et al. (2016) suggest offering a well-defined start and end of a session game to support the understanding of tasks.
- Actively promote communication, for example, through visual and audio notifications that highlight the messages received, but without distracting from the main activity (Keskinen et al., 2012). There are also tasks that require join-attention (Sharma et al., 2016).

5. Conclusion

In this article, we presented a systematic review of literature aimed at identifying the aspects of collaboration support and collaborative strategies included in co-located collaborative systems, in order to contribute to the treatment of impairments in individuals with ASD. We identified three main answers related to the three proposed research questions:

1. Initially, we reviewed how co-located collaborative systems in the literature encourage the collaborative work of individuals with ASD. We found in the studies that collaborative work is encouraged by different characteristics in the collaborative systems, mainly through the use of specific methods of interaction in the systems that we called collaborative strategies.

We verified that most of the studies utilize strategies that somehow "enforce" user collaboration. Only three studies do not "enforce" collaboration, as they include strategies to guide and support users in collaborative activities (*Stimulating Collaboration* strategy). Some studies present collaborative applications that allow free interaction among users to collaborate (*Free Collaboration* strategy).

The studies using only the *Stimulating Collaboration* and *Free Collaboration* strategies do not present results about their contribution to collaborative work. On the other hand, all the studies using restrictive strategies show promising results on the effects of collaborative systems in users assessed. According to the results observed in the studies, we highlight the benefits of including different strategies (restrictive and/or free strategies) in the same application to encourage the collaborative work (Boyd et al., 2015; Giusti et al., 2011; Ribeiro et al., 2014; Silva et al., 2015, 2014; Silva-Calpa et al., 2018). We highlight also the contribution of the *Taking Turns* and *Simultaneous Interaction* strategies to encourage social, language and collaboration skills of users with different levels of ASD. It is important to note the contribution of strategies that "enforce" activities, as well as support the collaborative process to encourage the performance of collaborative activities, especially for ASD users with more severe impairments, as pointed out in (Battocchi et al., 2009): "If collaboration wasn't enforced, would more likely work independently and perhaps ignore each other."

We emphasize the need for carrying out in-depth studies on the design and evaluation of collaborative systems using the *Stimulating Collaboration* strategy to clearly identify their contribution in users with ASD. We encourage studies on the design of collaborative systems intended for users with ASD that have high difficulty in identifying and getting involved with collaborative activities. The aim is to identify how to provide suitable collaboration support to suit the users' needs so they can easily perform the activities required and stay motivated.

The second question reviewed in the studies consists of identifying collaboration support mechanisms provided by co-located collaborative systems. We found a single study that specifically aims at providing other-awareness support (Holt & Yuill, 2017) showing interesting results, and another study that reports positive contributions of support mechanisms to the other's actions awareness (Villafuerte et al., 2012). We also highlighted a single study (Silva-Calpa et al., 2018) that explicitly mentions providing collaboration support through interface elements, intended for individuals with severe ASD.

We identified that some studies show different interface elements that support collaboration, such as visual and auditory feedback, simple visual representations, virtual tutor, different colors, and photos with names of the participants. Some of these studies report that the visual and auditory feedback provided helped to guide the interaction of users (Silva-Calpa et al., 2018), encourage their performance (Battocchi et al., 2009) (Sharma et al., 2016), and identify the user's turn to be taken (Roldan-Alvarez et al., 2014). One study reports the benefits of the virtual tutor guidance during tasks (Marco et al., 2013). However, most of the studies do not explain how the mechanisms used supported the proposed collaborative process; there are no indications that these elements were evaluated to identify meaningful contributions to interactive and collaborative improvement among users. The lack of implementation and assessment of collaboration support mechanisms indicates the need for in-depth research to develop such systems. It must be taken into consideration that unlike systems designed for typically developing individuals, users with ASD, regarding their ToM condition, need awareness support to perform collaborative activities.

In this sense, several questions are raised and dealt with in research that contribute to the development of better co-located collaborative systems, especially the ones designed for individuals with severe impairment related to ASD. For example, which characteristics must the interface have to attract the user's attention and motivate them to perform the activities? How should these characteristics be designed to meet the needs of ASD users with different levels of impairment? How can collaborative systems support users with ASD in the identification of the tasks, their partner's actions, and the necessary interaction in the workspace? How can users be encouraged to collaborate?

It is worth mentioning that in addition to the support provided by the collaborative system, the therapist's support is essential in studies involving individuals with ASD. The studies analyzed stressed the importance of the therapist's intervention to provide physical and behavioral support and facilitate activity comprehension.

3. Finally, we found that the analyzed studies offer some recommendations for the design of co-located collaborative systems. The authors from these studies brought forth these recommendations after carrying out empirical assessment studies on users with ASD. We believe that these are very important for the development of collaborative systems intended for ASD individuals, as they can improve the development of collaboration support mechanisms; they should be thoroughly studied so that updated requirements may be issued.

Besides these three aspects related to this study's research questions, our review verified that only a few studies were developed specifically for ASD users with severe impairment, who needed substantial support to perform collaborative activities. Therefore, we have identified the need for carrying out in-depth studies on the development of co-located collaborative systems with distinguishing features to encourage users with severe impairment to collaborate.

The findings of this review foster new avenues of research on the design of collaborative systems, which include support collaboration and proper features so that users can perform activities by reacting to certain input, as well as identifying their own actions and their pattern's actions as well. Utlimately, we believe that the development of these systems should take into consideration that not all users possess the intrinsic characteristics needed to collaborate.

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We have no conflicts of interest to disclose.

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Francisco R. Ortega is an Assistant Professor in Computer Science at Colorado State University and Director of the natural user interaction lab (NUILAB). His expertise is in the areas of 3D User Interfaces and Human-Computer Interaction. Broadly speaking, his research has focused on gesture interaction, which includes multimodal interaction (gesture-centric).

Appendix. Primary studies

	Article	Author(s)	Journal/Conference	Year
	IEEE Xplore			
1	CoASD: A tabletop game to support the collaborative work of users with autism spectrum disorder	Greis Francy M. Silva-Calpa, Alberto B. Raposo, and Maryse Suplino.	IEEE 6th International Conference on Serious Games and Applications for Health (SeGAH)	2018
2	Benefits of Combining Multitouch Tabletops and Turn-Based Collaborative Learning Activities for People with Cognitive Disabilities and People with ASD	David Roldán-Álvarez, Ana Márquez-Fernández, Silvia Rosado-Martín, Estefanía Martín, Pablo A. Haya, Manuel García-Herranz	IEEE 14th International Conference on Advanced Learning Technologies	2014
3	ComFiM: A Cooperative Serious Game to Encourage the Development of Communicative Skills between Children with Autism	Paula Ceccon Ribeiro, Bruno Baère Pederassi Lomba de Araujo, Alberto Raposo	Brazilian Symposium on Computer Games and Digital Entertainment	2014
4	Usability of technology supported social competence training for children on the Autism Spectrum	Patrice L. Weiss, Eynat Gal, Massimo Zancanaro, Leonardo Giusti, Sue Cobb, Laura Millen, Tessa Hawkins, Tony Glover, Daven Sanassy, Sigal Eden	International Conference on Virtual Rehabilitation	2011
	ACM Digital Library			
1	On Active Sharing and Responses to Joint Attention Bids by Children with Autism in a Loosely Coupled Collaborative Play Environment	Tiffany Y. Tang, Pinata Winoto, and Aonan Guan	Proceedings of the 2017 Conference on Interaction Design and Children	2017
2	Promoting Joint Attention with Computer Supported Collaboration in Children with Autism	Sumita Sharma, Saurabh Srivastava, Krishnaveni Achary, Blessin Varkey, Tomi Heimonen, Jaakko Samuli Hakulinen, Markku Turunen, Nitendra Rajput	Proceedings of the 19th ACM Conference on Computer-Supported Cooperative Work & Social Computing (CSCW'16)	2016
3	I will Help You Pass the Puzzle Piece to Your Partner if This is What You Want Me to: The Design of Collaborative Puzzle Games to Train Chinese Children with Autism Spectrum Disorder Joint Attention Skills	Pinata Winoto, Tiffany Y. Tang, and Aonan Guan	Proceedings of the The 15th International Conference on Interaction Design and Children (IDC '16).	2016
4	Evaluating a Collaborative iPad Game's Impact on Social Relationships for Children with Autism Spectrum Disorder	Louanne E. Boyd, Kathryn E. Ringland, Oliver L. Haimson, Helen Fernandez, Maria Bistarkey, Gillian R. Hayes	ACM Transactions on Accessible Computing (TACCESS): V.7 Issue 1, June 2015	2015
5	Collaborative tablet applications to enhance language skills of children with autism spectrum disorder.	Bimlesh Wadhwa, Clarence Cai Jianxiong	Proceedings of the 11th Asia Pacific Conference on Computer Human Interaction (APCHI '13)	2013
6	Encouraging collaboration in hybrid therapy games for autistic children	Sebastian Marwecki, Roman Rädle, Harald Reiterer	Extended Abstracts on Human Factors in Computing Systems (CHI EA '13)	2013
7	Evaluation of tablet apps to encourage social interaction in children with autism spectrum disorders	Juan Pablo Hourcade, Stacy R. Williams, Ellen A. Miller, Kelsey E. Huebner, Lucas J. Liang	Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '13)	2013
8	Acquisition of social abilities through musical tangible user interface: children with autism spectrum condition and the reactable	Lilia Villafuerte, Milena Markova, Sergi Jorda	Extended Abstracts on Human Factors in Computing Systems (CHI EA '12)	2012
9	Dimensions of collaboration on a tabletop interface for children with autism spectrum disorder	Leonardo Giusti, Massimo Zancanaro, Eynat Gal, Patrice L. (Tamar) Weiss	Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '11)	2011
10	In my own words: configuration of tangibles, object interaction and children with autism	William Farr, Nicola Yuill, Eric Harris, Steve Hinske	Proceedings of the 9th International Conference on Interaction Design and Children (IDC '10)	2010
11	Collaborative Puzzle Game: Fostering collaboration in children with autistic spectrum disorder (ASD) and with typical development	A. Battocchi, F. Pianesi, D. Tomasini, M. Zancanaro, G. Esposito, P. Venuti, A. Ben Sasson, E. Gal, P. L. Weiss	Proceedings of the ACM International Conference on Interactive Tabletops and Surfaces (ITS '09)	2009
12	SIDES: a cooperative tabletop computer game for social skills development	Anne Marie Piper, Eileen O'Brien, Meredith Ringel Morris, and Terry Winograd	Proceedings of the 20th anniversary conference on Computer supported cooperative work (CSCW '06)	2006
	Science Direct			
1	Tablets for two: How dual tablets can facilitate other-awareness and communication in learning disabled children with autism	Samantha Holt, Nicola Yuill	International Journal of Child-Computer Interaction, Volume 11, Jan. 2017, Pages 72–82	2017
2	PAR: A Collaborative Game for Multitouch Tabletop to Support Social Interaction of Users with Autism	Greis F. Mireya Silva, Alberto Raposo, Maryse Suplino	DSAI 2013 Procedia Computer Science, Volume 27, 2014, Pages 84–93	2014
3	Computer mediated imaginative storytelling in children with autism	Gayle Dillon, Jean Underwood	International Journal of Human-Computer Studies, Volume 70, Issue 2, Feb.2012, P. 169–178	2012
4	SymbolChat: A flexible picture-based communication platform for users with intellectual disabilities	Tuuli Keskinen, Tomi Heimonen, Markku Turunen, Juha-Pekka Rajaniemi, Sami Kauppinen	Interacting with Computers, Volume 24, Issue 5, September 2012, P.374–386	2012
	Springer Link			
1	Exploring Collaboration Patterns in a Multitouch Game to Encourage Social Interaction and Collaboration Among Users with Autism Spectrum Disorder	Greis F. Mireya Silva, Alberto Raposo, Maryse Suplino	Computer Supported Cooperative Work (CSCW), June 2015, Volume 24, Issue 2, pp 149–175	2015

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	Article	Author(s)	Journal/Conference	Year
2	Bringing tabletop technology to all: evaluating a tangible farm game with kindergarten and special needs children	Javier Marco, Eva Cerezo, Sandra Baldassarri	Personal and Ubiquitous Computing, Dec 2013, Volume 17, Issue 8, pp 1577–1591	2013
3	Multitouch tablet applications and activities to enhance the social skills of children with autism spectrum disorders	Juan Pablo Hourcade, Natasha E. Bullock-Rest, Thomas E. Hansen	Personal and Ubiquitous Computing, February 2012, Volume 16, Issue 2, pp 157–168	2012
4	Enhancing social communication of children with high-functioning autism through a co-located interface	Eynat Gal, Nirit Bauminger, Dina Goren-Bar, Fabio Pianesi, Oliviero Stock, Massimo Zancanaro, Patrice L. (Tamar) Weiss	AI & SOCIETY, August 2009, 24:75	2009
	SAGE Journals			
1	To enforce or not to enforce? The use of collaborative interfaces to promote social skills in children with high functioning autism spectrum disorder	Ayelet Ben-Sasson, Liron Lamash, Eynat Gal	AUTISM, September 2012, Volume: 17 issue: 5, pp 608–622, 2013	2013
2	Increasing social engagement in children with high-functioning autism spectrum disorder using collaborative technologies in the school environment	Nirit Bauminger-Zviely, Sigal Eden, Massimo Zancanaro, Patrice L Weiss, Eynat Gal	AUTISM, April 2013, Volume 17, Issue 3, pp 317–339	2013