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Enhancing daily living skills in four adults with autism spectrum disorder through an embodied digital technology-mediated intervention

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ABSTRACT

Background: The acquisition of daily living skills is fundamental in the education of people with Autism Spectrum Disorder (ASD), especially of those with Intellectual Disability (ID), because this can significantly contribute to their autonomy, self-confidence and overall life satisfaction. The purpose of this study was to assess the impact of an embodied Digital Technology (DT)-mediated intervention, compared to a Treatment-As-Usual (TAU) intervention, for enhancing two daily living skills: washing dishes and doing laundry.
Method: Four males of between 25 and 37 years old with ASD and ID participated in the study. The two interventions were based on audio and picture prompting instructional techniques aimed at helping participants to off-load cognitive work onto the environment. The DT-mediated intervention consisted of the use of a tablet connected to a lighting system. The TAU intervention consisted of the use of paper-based pictures and task strips. A reversal single-subject experimental design across participants was conducted in a day centre.
Results: Data showed that the DT-mediated intervention was more effective than the TAU intervention in reducing the number of educator prompts given to three of the four participants, and for diminishing the number of off-task behaviours showed by all participants during the performance of the activities.
Conclusions: A novel DT-mediated intervention effectively enhanced participants' daily living skills. The major novel contribution of this work is to show that the use of a handheld device connected to a lighting system can be an effective method for the interaction and embodiment of people with ASD and ID in a real-world setting.

1. Introduction

Giving priority to the acquisition of daily living skills is fundamental in the education of people with Autism Spectrum Disorder (ASD), especially of those with concomitant Intellectual Disability (ID), for three main reasons. Firstly, difficulties in the performance of daily living activities can severely affect their participation in household routines. This in turn may have a negative impact on their sense of self-worth, self-confidence and overall life satisfaction (Vermeulen, 2013), and even lead to the development of learned helplessness (Peterson, Maier, & Seligman, 1993). Secondly, the lack of daily living skills makes these people more dependent on others and so the need of continuous supervision and care provided by parents, educators and practitioners may be perpetuated

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(Jordan, 2013). As a result, these people's autonomy becomes limited and the chances for them to live on their own seem unlikely. Thirdly, not being skilful in daily life activities might prevent people with ASD and ID from getting and keeping an employment, which is considered to be a factor of paramount importance for having a meaningful life (Pellicano, Dinsmore, & Charman, 2014). For these reasons, enhancing daily living skills has been the ultimate objective of many previous research studies that targeted the needs of people with ASD (Gardner & Wolfe, 2013; Hong et al., 2016; Weaver, 2015) as well as the needs of people with other Developmental Disabilities (DDs) such as ID (Ayres, Mechling, & Sansosti, 2013; Den Brok & Sterkenburg, 2015; Ramdoss et al., 2012).

1.1. Digital Technologies for the enhancement of daily living skills in people with ASD

The contribution of Digital Technologies (DT) for the enhancement of daily living skills in the target population has been prominent. A comprehensive systematic review indicated that handheld devices such as Personal Digital Assistants (PDAs) and, more recently, tablets and smartphones have become the most popular DT for enhancing daily living skills in people with ASD and other DDs (Pérez-Fuster, 2017). The major advantages of these devices compared to other DTs are that they (a) are portable, (b) can take/record, store and display pictures and videos, (c) have become more and more affordable and accessible, and (d) can be successfully used by people of different ages and cognitive abilities requiring different levels of support through – generally embedded – helpful features such as the *Guided Access* mode[1], and also a wide range of commercially available screen protectors, covers and cases. Handheld devices have been used for teaching a broad variety of daily living skills. For instance, PDAs have been used for teaching independent transitioning between daily activities (Mechling & Savidge, 2011; Palmen, Didden, & Verhoeven, 2012) and cooking recipes (Mechling, Gast, & Seid, 2009; Mechling, Gast, & Seid, 2010). More recently, tablets have been used for teaching shopping skills (Burckley, Tincani, & Guld Fisher, 2015), laying the table (Spriggs, Knight, & Sherrow, 2015), folding clothes and cleaning the bathroom (Aldi et al., 2016), cleaning the table, countertop and microwave (Cullen, Simmons-Reed, & Weaver, 2017), folding towels and vacuuming (O'Handley & Allen, 2017). Smartphones have been used for teaching people to use a washing machine and making noodles (Bereznak, Ayres, Mechling, & Alexander, 2012), and for computer and mobile technology skills instruction (Smith, Shepley, Alexander, Davis, & Ayres, 2015). Moreover, other small handheld devices (i.e., MP4 players) have been used to teach sweeping and table washing (Cannella-Malone, Wheaton, Wu, Tullis, & Park, 2012) as well as window washing (Wu, Cannella-Malone, Wheaton, & Tullis, 2016).

The instructional techniques that have been used for enhancing daily living skills in people with ASD through handheld devices are varied, including audio prompting (Palmen et al., 2012), picture prompting, video modelling (Aldi et al., 2016; O'Handley & Allen, 2017; Smith et al., 2015), video prompting (Bereznak et al., 2012; Cullen et al., 2017; Wu et al., 2016), and a combination of two or more of these methods (Burckley et al., 2015; Mechling & Savidge, 2011; Mechling et al., 2009; Spriggs et al., 2015). A review conducted by Ayres et al. (2013) indicated that, whereas video modelling is limited in the sense that it still requires direct intervention of human instructors in the setting to provide support, audio and picture prompting and video prompting have been found to be an important support for the people's independent performance in day-to-day activities. Audio and picture prompting, as opposed to video prompting, can be administered through the use of DTs as well as the use of other conventional systems (e.g., a combination of paper-based materials and a human instructor). This allows for the comparison of two teaching methods that are based on the same instructional technique (i.e., audio and picture prompting) but use a different channel (i.e., DT vs. non-DT). Although few of the above-mentioned studies also included video prompting, they applied this research formula indicating that the use of two different DTs (i.e., PDA and tablet), compared to the use of non-DT methods (i.e., prompting provided by visual cues and human instructors), was more effective for the enhancement of shopping (Burckley et al., 2015), cooking (Mechling et al., 2009) and transitioning (Mechling & Savidge, 2011) skills in seven adolescents and young adults with ASD and ID. Regarding the variables measured, most studies have looked at the number of tasks the person has completed correctly on his/her own. Furthermore, the number of prompts provided by the instructor to redirect people's off-task behaviours (e.g., engaging in self-stimulation or stereotypical behaviours) has been considered an important measure of intervention effects (Mechling & Savidge, 2011).

Although the above-mentioned DT methods were effective compared to non-DT methods, the studies did not purposely look for extending the embodied skills of the participants with ASD.

1.2. Embodied cognition and interaction

Embodied Cognition Theory assumes that some features of cognition are shaped by aspects of the entire body organism, and this also includes the individual's bodily interactions with the environment (Clark, 1997, 1998). Learning and performing daily living skills involves the manipulation of a range of physical objects. For instance, performing the activity of washing dishes may imply the interaction with a set of dirty dishes, soap, a sponge, a dish rack and a kitchen cloth. Gibson (1979) stated that the world is perceived not only in terms of object shapes and spatial relationships but also in terms of object possibilities for action, what he called *affordances* (e.g., the handle of a tea cup provides an affordance for holding). Loveland (1991) stated that people with ASD fail to perceive some affordances that are easily grasped by others of similar mental age (e.g., people with ASD may use objects in

[1] *Guided Access* mode allows Apple handheld devices (i.e., iPod, iPhone and iPad) users to (a) temporarily restrict the device to a single application, (b) disable areas of the screen that are not relevant to a given task, or areas where an accidental or intentional gesture might cause a distraction, and (c) disable the hardware buttons. An equivalent feature called *Interaction Control* is also available for some Android operative system devices.

stereotypes ways like banging them, lining them up or spinning them) and sometimes select idiosyncratic affordances. An example of this is when a person with ASD only drinks from one particular cup; in such a case, the affordances of other cups are not perceived, are misperceived, or are rejected. As perception drives action, these difficulties can be seen as a barrier for culturally accepted embodied interactions in ASD.

Wilson (2002) suggested six views of embodied cognition; one of these views refers to the fact that humans "off-load cognitive work onto the environment" (p.628) due to limits in attention and working memory (e.g., at home, some prepare a bag with the things they want to take and leave it close to the door so not to forget it). People with ASD show an atypical interaction between perception and attention in the form of a *local bias* or attentional orientation toward parts over wholes, that contrasts with the typical bias in favour of global targets (Mottron & Burack, 2012; Wang, Mottron, Peng, Berthiaume, & Dawson, 2007). People with ASD also show difficulties in working memory (Vogan, Francis, Morgan, Smith, & Taylor, 2018). Therefore, the environment can play a key role in the off-loading of cognitive work in embodied interactions in ASD.

1.3. The importance of a structured environment

An intervention program which seeks to provide a structured environment to effectively teach individuals with ASD is the Treatment and Education of Autistic related Communication Handicapped Children (TEACCH) program (Mesibov, Shea, & Schopler, 2005). The TEACCH approach is based on the available evidence that individuals with ASD share a pattern of neuropsychological deficits and strengths, with special preferences in the type and sensory format of information and with the need for structures that guide people's attention during tasks. This approach has been widely used to promote autonomy in children and adults with ASD in a variety of cognitive and adaptive domains, including daily living skills.

The Individual Work System (IWS) is one of the structures used in the TEACCH approach to visually communicate the learner four pieces of information: (a) the tasks, (b) the amount of work to be completed, (c) a signal that the work is finished, and (d) instructions for the next activity in their schedule. The effectiveness of IWS for increasing on-task behaviour and work completion of learners with ASD, and for decreasing the needs for trainer prompting has been demonstrated in school and work settings (Bennett, Reichow, & Wolery, 2011; Hume & Odom, 2007; Hume, Plavnick, & Odom, 2012). Therefore, the IWS can be seen as an effective strategy to adapt the environment so that affordances for interaction become *visible* and salient for people with ASD, allowing them to have embodied interactions that can promote their learning and activity performance.

1.4. Embodied DT-mediated interventions for enhancing daily living skills

Embodied interactions are not limited to the use of physical objects, but it is also extended to the use of DT. The above-mentioned term *affordance* was also applied in the field of human-computer interaction to refer to action possibilities that are readily perceivable by the DT user (Norman, 1988). An example of embodied DT that can help the user to off-load cognitive work onto the environment (Wilson, 2002) consists of the use of a tablet with a calendar that displays visual and/or auditory prompts for the person to direct his/her attention towards an object to interact with it. Embodied DT therefore has features that can disable, guide, or empower people's bodily actions (Boer, Mitchell, Caglio, & Lucero, 2015) and have the potential to support people with ASD in their daily life.

According to Huang, Cherubini, Nova, and Dillenbourg (2009), there has been a shift from seeing objects and furniture as containers or pedestals for computing, to a view of furniture as communication vectors. In this context, the lighting of an array of LED (i.e., Light Emitting Diode) that goes from the person who speaks to the person who listens has been used to provide people with augmented information in face-to-face conversational situations (Nikolovska & Ackermann, 2009). Furthermore, there is an ongoing project called MyDayLight which, using a participatory design approach with three adults with ASD and from mild to non-ID, has explored the use of a lighting system as an artefact to support people in daily life (Kopke & Van Dijk, 2017; Van Dijk & Hummels, 2017). The system is formed of small wireless and portable lamps which light up to give hints. The idea is that the person with ASD puts a number of these lamps in significant places at home and schedules on a digital calendar the activity s/he wants to do. Then, on the scheduled day and time, the corresponding lamp lights up to help the person to attend to what s/he wanted to do (e.g., the dishes in a kitchen environment). This has been presented as a non-directive support tool aimed at empowering users to look at the environment and to interact with the objects that surround them. This tool can help to reduce many people's cognitive workload and attention difficulties by limiting the information they need to memorise and reminding them where to look. However, there are people with ASD and more severe ID who may still require (a) support from others in scheduling activities on a calendar and (b) prompts from human instructors or handheld devices to perform activities correctly. This gap in the framework of embodied DT and the contribution of the handheld devices and the IWS to the learning of people with ASD motivated the development of a novel system, which is described in the following.

1.5. The ETIC system

This study was developed in the framework of a more comprehensive research project that aimed at developing a system to empower the interaction and embodiment of people with ASD and ID with the real world in daily living activities. The system was co-designed by an interdisciplinary team formed of (a) two computer engineers, one electronics engineer, (b) the authors of this paper (i.e., two computer engineers and one psychologist) and (c) members of a day centre that participated in the project, including two educators and two psychologists who work with adults with ASD and ID. A number of meetings were arranged throughout the system development in which the staff members of the day centre, as co-designers, provided with input on the strengths and interaction

Fig. 1. Components of the ETIC system.

needs of the participant adults with ASD and ID with the ultimate goal of creating an ecologically-valid tool. The final version of the system consisted of: (a) a web server application with a user interface running on Linux Operative System (OS), (b) a mobile application for Android OS, and (c) a hardware-based home automation solution with a LED lighting system (see Fig. 1).

The web interface was designed for parents, educators and practitioners to create user profiles, describe user characteristics, upload visual supports (e.g., pictures) and schedule activities on a calendar. This information could be remotely modified by connecting to the system network via any web browser. The calendar automatically synchronised with the mobile application for the user to have access through his/her tablet or smartphone to the visual supports that had been selected for him/her in advance for performing activities. The mobile application had (1) an activity board, where all the pictures representing the scheduled activities were shown, and (2) a task board that opened right after the user selected an activity. The task board displayed items in two different areas of the screen. On the upper side, the user could see all the pictures that formed an activity, each picture representing one specific task. Following the IWS principles, the pictures were shown one after another, in the order in which the tasks had to be performed, and the pictures could be explored by placing one finger gently on one of them and moving it towards the sides. When the user touched and held one of these pictures, it was shown enlarged in the middle of the screen and, if programmed, could play an audio clip (e.g., for audio prompting) as many times as the user touched it. To move to the next task, the user had to touch the next picture at the top for this to appear in the middle of the screen and play the corresponding audio clip, and so on. The mobile application could be customised according to user preferences and interests (e.g., background colour, visual supports) from the settings of the web interface. Moreover, the interaction with the mobile application could have effects on a LED lighting system, which was designed to help the users to easily find the place where they needed to go in the real world to perform a given task. When the user touched one of the pictures, apart from displaying an audio clip, a set of small LED lights could also be automatically switched on. The time for which the lights would be switched on after the user touched the picture could also be customised on the web interface.

Using this system in a structured teaching environment could help people to better associate the instructions and prompts they receive on the tablet or smartphone with the specific location they need to get to in the real world in order to perform daily living activities autonomously.

1.6. Purpose of this study

The purpose of this study was to evaluate the impact of a DT-mediated intervention that is based on the use of the ETIC system on the enhancement of two daily living skills (i.e., washing dishes and doing laundry) in four adults with ASD and ID who attended the day centre where the ETIC system was developed. The DT-mediated intervention was compared to a Treatment-As-Usual (TAU) intervention that consisted of an adapted IWS. Both interventions used audio and picture prompting techniques aimed at helping participants to off-load cognitive work onto the environment. The DT-mediated intervention was based on the use of a tablet which was connected to a lighting system. The TAU intervention was based on the use of paper-based picture schedules and one educator. The research questions addressed were as follows: (a) would the participants perform the target activities with fewer educator prompts when using the DT? and (b) would the DT-mediated intervention lessen the participants' off-task behaviours during the performance of the target activities?

2. Methods

2.1. Participants

In order to be included in the study, participants met the following criteria: (a) they had a formal diagnosis of ASD and ID according to the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013), and (b) they did not have any motor or visual impairment. These criteria were confirmed through assessments conducted by

Table 1
Participant characteristics.

Participant	Gender	Chronological age	DSM-5 (Diagnosis)	ABS-RC:2 *Personal Self-Sufficiency* (Coefficient, age equivalence)	ICAP (Level of support needed, age equivalence)	SIS *Home Living* (Level of support needed)
P1	Male	31	ASD (Level 3) with intellectual and language impairment	85, 15	3, 5:8	12
P2	Male	26	ASD (Level 3) with intellectual and language impairment	88, 15	3, 4:5	12
P3	Male	25	ASD (Level 3) with intellectual and language impairment	80, 15	3, 3:2	14
P4	Male	37	ASD (Level 3) with intellectual and language impairment	64, < 3	4, 2:4	12

psychologists and medical doctors before this study started. Four males aged between 25 and 37 years were selected as participants (see Table 1).

A 40-year old male psychologist who also was the Head of the day centre participated in the study. His main role was to evaluate the participants' daily living skills. A 30-year old female adult educator (hereafter, referred to as *the educator*), who was responsible of the participants' daily learning, also participated in the study. Her main role was to inform of participants' strengths and needs, and to implement the target interventions throughout the study. Prior to the start of the study, the Head of the day centre and the educator provided with additional participant information that is shown in Table 2.

Table 2
Description of participant language skills, strengths, behavioural difficulties shown when performing daily living tasks and previous experience using DT.

P1	
Language skills	*Production:* he had literacy skills. His verbal language was characterised by the presence of echolalia. He could produce long sentences with a wide vocabulary range. He could hold a conversation, although topics were very often restricted to his interests (e.g., car number plates). *Comprehension:* he understood instructions that imply making a decision or performing a sequential task.
Strengths	He was cheerful and talkative. He was highly interested in old cars and numbers. He was warm and enjoyed much interacting with peers.
Difficulties performing tasks	He lacked perseverance and attention. He needed somebody's continuous support to successfully complete the activities. When he was nervous, he might use obscene language and, when he became angry and/or frustrated, he may show self-injury behaviour (i.e., biting his hands). He had a number of stereotyped behaviours (e.g., arm flapping).
Experience with DT	He did not use a handheld device on a regular basis but when he accidentally interacted with one, he did not reject it.
P2	
Language skills	*Production:* he used verbal language although this was limited. He did not produce sentences, he only used words to name things that were very familiar to him. He rarely held a conversation. *Comprehension:* he understood instructions that imply making a decision or performing a sequential task. It was possible to get functional answers that matched with the questions made to him.
Strengths	He was tidy and very organised. He was flexible to some extent. He had some basic daily living skills that facilitated him to learn more sophisticated tasks.
Difficulties performing tasks	He often rejected to perform activities and tended to escape from the place where he was meant to perform the activity. His willingness for performing household tasks was scarce. When he felt anxious, he might take his clothes off in inappropriate situations and/or throw objects.
Experience with DT	He did not have previous experience with any handheld device, but he generally showed interest towards novelties so no rejection towards the use of DT could be expected a priori.
P3	
Language skills	*Production:* he had very limited verbal language with echolalia. *Comprehension:* he could respond correctly to short and very simple questions.
Strengths	He was quiet and friendly. He easily collaborated with others and he was pretty adaptable.
Difficulties performing tasks	He used to invest much time in completing the activities and he constantly required others' supports to succeed. When he became nervous, he often self-harmed by severe nail and finger biting.
Experience with DT	He did not use any handheld device on a daily basis but when he interacted by chance with one, he did not reject it.
P4	
Language skills	*Production:* he did not use verbal language, but he often expressed his emotions (e.g., happiness, anger) through specific noises and body movements. *Comprehension:* he could respond using his gaze and other gestures to his name and to simple sentences.
Strengths	He was orderly and methodical. He was skilful for integrating concepts correctly. He was very good at colouring following chromatic scales.
Difficulties performing tasks	He needed much supervision to do most daily living activities and required full support to complete some of them. In case of frustration, he wanted to be left on his own and he could bang his head against walls and doors.
Experience with DT	He did not regularly use any handheld device and when he saw one close, he did not show any interest and he even refused to touch it.

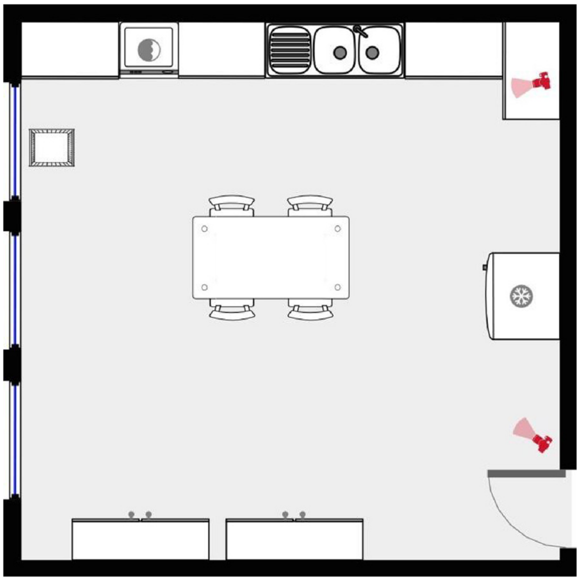

Fig. 2. *Home-room*: the setting where this study was conducted.

2.2. Setting

Participants were recruited from a day centre for adults with ASD which located in the province of Valencia (Spain). This centre belongs to a non-profit organization whose principal aim is to provide people with opportunities for labour and social integration. Participants attended the centre from Monday to Friday, for eight hours each day, to learn how to perform a wide range of activities (e.g., gardening, handcrafting). The setting chosen for this study was an indoor room called *Home-room,* which was equipped with a table, chairs, a fridge, a kitchen sink, a washing machine, a laundry basket and multiple cupboards as shown in Fig. 2. This is the setting where adults with ASD performed daily living activities such as preparing food, washing dishes or doing laundry.

Home-room's layout and organization and administration of activities were based on the TEACCH program (Mesibov et al., 2005). Hence, before this study started, this room already offered (a) physical organization (i.e., a given space was dedicated to a specific task), (b) individualised schedules, and (c) visual structure of materials in tasks and activities. Individualised schedules were provided by means of laminated paper-based pictures secured by Velcro onto a wallboard, between the fridge and one of the cupboards. Each picture represented a certain activity. A person's individualised schedule board had as many pictures as activities the person had to perform in a day. To start performing an activity, the person took the corresponding picture and placed it onto a task strip which was located next to it. The task strip, in turn, was formed of as many pictures as the number of tasks the activity was composed of, so each picture represented one single task. Each picture of the task strip had one number that was associated with the order in which that task had to be performed in order to successfully complete the activity. Once the activity was completed, the person placed the picture that represented that activity into a *finished box*, located below his schedule board.

2.3. Materials

2.3.1. Standardised tools for evaluating daily living skills

Prior to the start of the study, the Head of the day centre administered the following tests to evaluate the participants' daily living skills. The most relevant outcomes are shown in Table 1.

2.3.1.1. Adaptive behavior scale: residential and community (ABS-RC:2) (Nihira, Leland, & Lambert, 1993). The Spanish version of the ABS-RC:2 (García, De La Fuente, & Fernández, 2010) was applied to assess the manner in which each participant coped with natural and social demands of his environment. This scale measures the skills and abilities necessary to perform daily living tasks in adults with ID. Although participants completed the full version of the test, scores are only given here for the factor *Personal Self-Sufficiency*, which is the one that is more closely related to the target skills (i.e., daily living). Scores are based on coefficients (0–69: very low; 70–79: low; 80–89: below the average; 90–110: average; 111–120: above the average; 121–130: superior; 131–160: very superior) and age equivalences.

2.3.1.2. Inventory for client and agency planning (ICAP) (Bruininks, Hill, Weatherman, & Woodcock, 1986). The Spanish version of the ICAP (Montero, 1996) was applied to assess adaptive and maladaptive behaviours that indicate the overall level of care and supervision required by each participant. *ICAP* provides valuable information about people's ability to function in different general areas including personal living skills. Scores shown in Table 1 are based on 5 levels of support needed (1: no support needed - or

Table 3
Items used for washing dishes and doing laundry.

Washing dishes	Doing laundry
A set of dirty dishes	A set of dirty clothes
A basket	A laundry basket
A sponge	Soap
Soap	Softener
A dish rack	
A kitchen cloth	

rarely needed -; 2: limited attention and periodic supervision; 3: periodic attention and frequent supervision; 4: intense attention and constant supervision; 5: total attention and full supervision) and age equivalences.

2.3.1.3. Supports Intensity Scale (SIS) (Thompson et al., 2004). The Spanish version of the SIS (Verdugo, Arias, & Ibáñez, 2007) was applied to identify and measure the supports needed for each person to successfully participate in various life activities. Although participants completed the full version of the scale, scores are only given here for *Home Living*, which is the group of activities that are more closely related to the target activities (i.e., daily living). Results are based on standard scores that range from 0 to 20, with a higher score indicating a higher need of support.

2.3.2. Materials used throughout the study

Apart from the appliances available at the *Home-room* (i.e., kitchen sink and washing machine), a number of items were required for washing dishes and doing laundry. These items are listed in Table 3. Furthermore, different items were used in each of the two intervention methods.

2.3.2.1. TAU intervention. Laminated paper-based pictures, schedule boards and task strips were used for implementing TAU sessions. Pictures were real colour photographs taken in the *Home-room* of the educator performing the two target activities (e.g., see the task sequence for doing laundry in Fig. 3).

2.3.2.2. DT-mediated intervention. The ETIC system was used with a laptop computer, a 7″ tablet and three sets of small LED lights. The LED lights were placed (1) next to the kitchen sink, (2) above the washing machine, and (3) above the laundry basket. Given that the mobile application was multiuser, and participants had the experimental sessions at different times, only one tablet was needed to run the study.

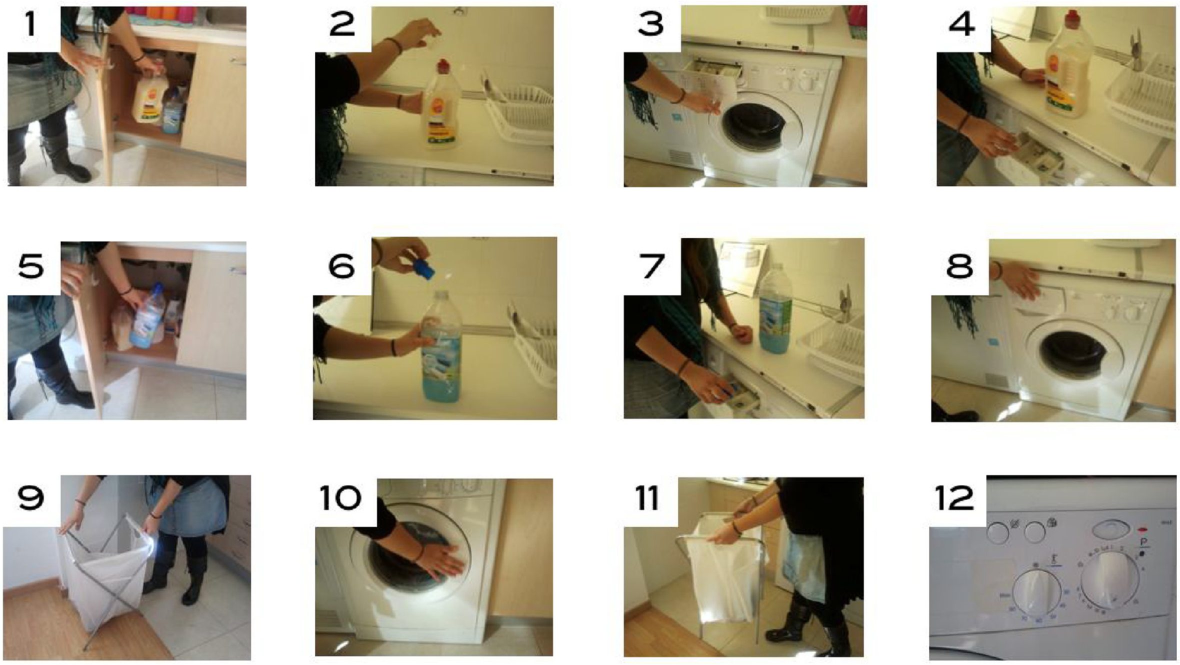

Fig. 3. Sample of the picture-based task sequence of the activity doing laundry.

Table 4
Tasks of the activities washing dishes and doing laundry.

Washing dishes	Doing laundry
1 Pick up the sponge	1 Open the cupboard
2 Open the tap	2 Take out the soap
3 Wet the sponge	3 Open the soap
4 Close the tap	4 Open the soap dispenser
5 Put down the sponge	5 Add soap
6 Take the soap	6 Close the soap
7 Open the soap	7 Put the soap back into the cupboard
8 Put soap on the sponge	8 Take out the softener
9 Put down the soap	9 Open the softener
10 Open the tap	10 Add softener
11 Wet the dishes	11 Close the soap dispenser
12 Take the sponge	12 Close the softener
13 Move the sponge over all the dishes	13 Put the softener back into the cupboard
14 Put down the sponge	14 Close the cupboard
15 Water the dishes	15 Take the washing basket
16 Close the tap	16 Put the basket close to the washing machine
17 Put the dishes on the dish rack	17 Open the door of the washing machine
18 Pick up the kitchen cloth	18 Put the clothes inside the washing machine
19 Dry your hands	19 Put the basket back
20 Put down the kitchen cloth	20 Close the door of the washing machine
	21 Select the washing program

2.4. *Design and procedures*

A reversal single-subject experimental design (Horner et al., 2005) was conducted with the four participants. The Head of the day centre and the educator, who were blind to some key points of the research design applied (e.g., they did not track in which number session each participant was at a given time), decided that P1 and P3 would perform the activity doing laundry and that P2 and P4 would perform the activity washing dishes. This decision was made based on (a) the participants' strengths and needs, (b) their educational curriculum and (c) the fact that they had been learning these activities for more than a year with no success to perform them autonomously so far. The tasks included in each of the two activities are shown in Table 4. The study lasted eight weeks and consisted of the following phases.

2.4.1. *Phase A, TAU intervention*

In each session of this phase, participants performed the assigned activity once, according to the methodology that they conventionally used in the *Home-room*. This consisted of the following: before the session started, the educator put the picture of the corresponding activity (i.e., a sponge with soap over a set of dishes for washing dishes and a washing machine for doing laundry) on his schedule, and either put (a) dirty dishes in a basket next to the kitchen sink or (b) dirty clothes inside the laundry basket. When the participant entered the room, he went to his schedule, took the picture, put it on the corresponding task strip and started the activity doing the task number one. He had to do all the tasks in order, and when he completed the last task he had to put the picture of the activity into the *finished box*. The educator taught him to correctly follow the picture-based task strip and properly use the items of the activity. She also provided him with verbal and gestural prompts throughout the performance of the activity. The activities were real (i.e., the dishes and the clothes actually needed to be washed). It was ensured that (a) the number of dishes and clothes used was similar across sessions, and (b) the educator would give instructions and would verbally (e.g., naming the tasks of Table 4) or gesturally (e.g., looking, pointing) prompt the participant only when he certainly needed support (e.g., he got distracted, he did not know how to continue). Additional sessions which followed this procedure but were conducted after Phase B or Phase C formed another phase called *Phase A'*.

During Phase A, the DT system was customised for the participants: (a) user profiles were created, (b) the same paper-based photographs they conventionally used (see Fig. 3) were uploaded into the system, and (c) the corresponding activities were scheduled on their calendars. Furthermore, the LED lighting system was installed in the room and wirelessly connected to the web interface and the tablet. Afterwards, participants learnt to use the DT system. The participants were asked to sit on a chair and the tablet was placed on the table in front of them. First, they explored the tablet. Then, the educator switched it on and, step by step, she instructed the participants to navigate through the tasks, to display the audio and picture prompting and to associate the connection between the selections made on the tablet and the switching of the lights. For this learning process, activities other than washing dishes and doing laundry were used (e.g., sweeping the floor).

2.4.2. *Phase B, DT-mediated intervention*

In each session of this phase, participants performed once the assigned activity using the DT system. This consisted of the following: before the session started, the educator put the tablet on the kitchen counter and either put (a) dirty dishes inside a basket next to the kitchen sink or (b) dirty clothes inside the laundry basket. When the participant entered the room, he went to the tablet and selected the activity that previously the educator had scheduled for him in the web interface: washing dishes or doing laundry. Then, the task board opened and he steadily touched the picture number one to receive the first audio and picture prompts to start with the first task. He could touch each picture as many times as he needed for audio self-prompting. When he correctly performed more than one task without using the tablet (e.g., with only one prompt he took the soap, opened it and put it in the soap dispenser), he was allowed to self-adjust the number of prompts by moving with his finger the task strip towards the left to look for the next task; that would avoid him viewing and hearing tasks he had already performed independently. After completing the last task, he touched the very last picture of the strip which functioned as a *finished button*. As in Phase A, the activities were real, the number of dishes and clothes was controlled to be similar across sessions (and also across phases), and educator prompts were only given when the participant required them.

2.4.3. Phase C, DT-mediated intervention with lights

In each session of this phase, participants performed once the assigned activity using the DT with the LED lighting system. This consisted of the same procedure described for Phase B. In addition, every time the participant self-prompted, the set of lights that corresponded to the place where he had to perform the task, switched on for seven seconds. This was thought to be long enough for participants to look at the target place and short enough for avoiding participants only focusing on the lights.

The number of sessions and the exposure to phases were different for each participant (see Fig. 4). All sessions were video-recorded using a camera which was placed in two different points of the room (see Fig. 2) depending on the target activity: the closest to the door was used for doing laundry and the closest to the kitchen sink was used for washing dishes. Two independent observers coded 100% of the videos.

2.5. Ethics statement

The current study was designed and implemented following the standards of the ethics committee for the empirical research with humans of the Universitat de València. This study also abides by The Ethical Principles for Medical Research Involving Human Subjects of the Declaration of Helsinki (World Medical Association, 2013). Before this study started, a meeting was arranged at the day centre in which the purpose of the study was explained to parents or legal tutors, the educator and the Head of the day centre. The staff members of the day centre signed an informed consent form for their participation. Given that the adults with ASD could not provide their own assent due to ID, one of their parents or legal tutors signed the consent form for each adult. All participants were informed of their right to withdraw from the study at any point.

2.6. Data analysis

Following the principles of the day centre, participants had to perform all the tasks correctly and successfully complete the target activity, with or without prompts. Accordingly, the number of tasks the participant performed independently correct was not considered in this study. Instead, the dependent variables were the number of educator prompts and participant off-task behaviours (see Table 5).

Inter-observer agreement (IOA) was calculated for all variables as the number of agreements between the two observers divided by the number of agreements plus the number of disagreements. Cohen's Kappa coefficient was also calculated by measuring the agreement between the two observers, subtracting agreement due to chance (Cohen, 1960). IOA can range from 0 to 1, with values higher than .80 indicating good IOA. Kappa can range from -1 to 1, and values higher than .70 indicate good inter-rater reliability. Besides, the *Percentage of All Non-Overlapping Data* (PAND) (Parker, Hagan-Burke, & Vannest, 2007) and Pearson *Phi* coefficients were calculated to evaluate the effect size of the DT-mediated intervention. On the one hand, PAND is a statistical technique that consists of the calculation of the total number of data points that do not overlap across different study phases. Firstly, it identifies overlapping data points (i.e., the minimum number of data points that would have to be transferred across phases for complete data separation). Secondly, it computes a percentage of overlap by dividing the number of overlapping points by the total number of data points. Thirdly, it subtracts this percentage from 100 to get PAND. A value higher than 90% indicates that the intervention is highly effective. On the other hand, Pearson *Phi* coefficient quantifies the differences between scores obtained in different study phases. A value higher than .70 indicates a strong positive association between the intervention and the outcomes.

3. Results

IOA and Cohen's Kappa coefficients higher than .90 and .80, respectively, indicated a very good inter-rater reliability. Results were plotted and are shown in Fig. 4. Based on the visual analysis of the graphs, it was observed that P1 received fewer educator prompts and showed fewer off-task behaviours in DT-mediated intervention sessions than in TAU intervention sessions. P2 also required much fewer educator prompts in DT-mediated intervention sessions than in TAU intervention sessions. Moreover, he showed only one – and even no – off-task behaviour in DT-mediated intervention sessions, which is a smaller number than that observed in TAU intervention sessions. P3 received fewer educator prompts in DT-mediated intervention sessions compared to TAU intervention sessions, especially, in Phase C in which the LED lighting system was functioning; it was observed that the number of educator prompts he was given gradually decreased throughout the sessions of this phase. Also, P3 showed a few off-task behaviours during the performance of the activity with the TAU intervention which lessened to one or even disappeared in DT-mediated intervention sessions. P4 required many educator prompts in all of the sessions regardless of the intervention. However, he showed fewer off-task

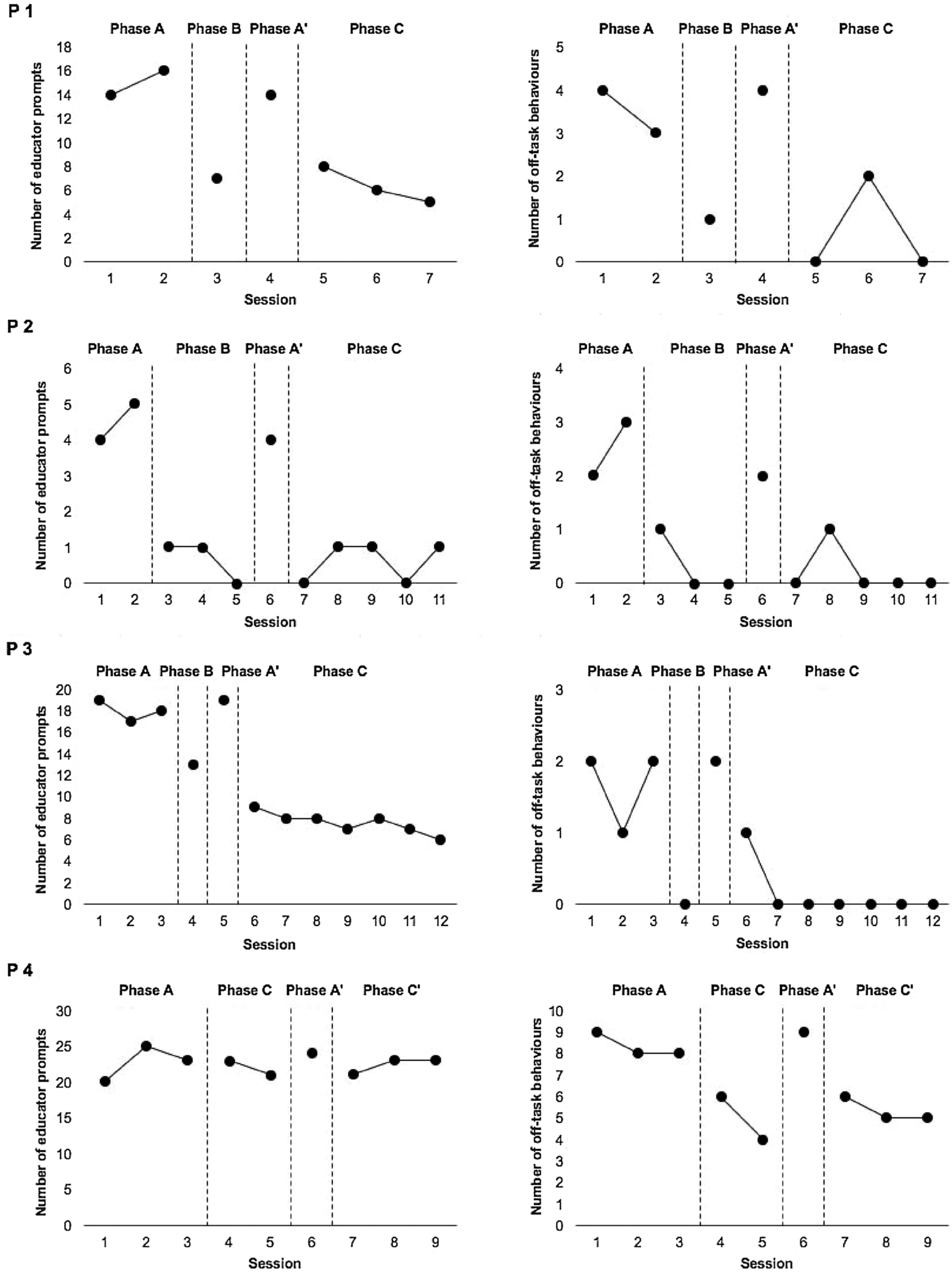

Fig. 4. Number of educator prompts and participant off-task behaviours throughout the study.

Table 5
Operationalisation of the measured variables.

Name of the variable	Description of the variable
Educator prompts	Number of times the educator verbally (e.g., naming a task, naming an item) or gesturally (e.g., pointing to an item, looking to a place) prompted the participant to help him to perform a task correctly during a session.
Off-task behaviour	Number of times the participant showed an off-task behaviour during a session. An off-task behaviour was described, partially following MacDuff, Krantz, and McClannahan, (1993) and Mechling and Savidge (2011) definitions, as (a) using task items for purposes other than performing the task; (b) using any non-task related items; (c) engaging in any stereotypical, self-stimulation or self-injury behaviours; or (d) not using any task items or not engaging in the task. This also included any of the *behavioural difficulties shown when performing daily living tasks* which are mentioned for each participant in Table 2.

behaviours in DT-mediated intervention sessions than in TAU intervention sessions.

An overall PAND of 95% and 97% were obtained for the number of educator prompts and the number of off-task behaviours, respectively. This shows that the DT-mediated intervention was highly effective (PAND $>$ 90%) for reducing these two measures during the performance of washing dishes and doing laundry in four adults with ASD and ID. Besides, Pearson *Phi* effect sizes of 0.89 ($p < .01$) and 0.93 ($p < .01$) were obtained for the same variables. This indicates a strong positive association (*Phi* > .70) between the DT-mediated intervention and the outcomes.

4. Discussion

The purpose of this study was to compare the effects of a DT-mediated intervention with a TAU intervention on the number of educator prompts and off-task behaviours of four male adults with ASD and ID during the performance of two daily living skills: washing dishes and doing laundry. The results indicate that the DT-mediated intervention, compared to the TAU intervention, was effective for (a) reducing the number of educator prompts received by three of the four participants, and (b) for diminishing the number of off-task behaviours showed by all participants during the performance of the activities. These findings show three important points. Firstly, the results of this study are in accordance with other studies that found that the use of handheld devices (e.g., Bereznak et al., 2012) were more effective than other conventional methods for enhancing daily living skills such as washing dishes or doing laundry. Secondly, this study showed that audio and picture prompting, delivered through a handheld device, can be an effective instructional technique for enhancing daily living skills, contributing so to the research body that has effectively used this in combination with other techniques such as video prompting (Mechling & Savidge, 2011; Mechling et al., 2009). Thirdly, the fact that the use of a DT system helped to diminish the participants' off-task behaviours, may be due to the acknowledged potential of DTs for facilitating people to engage in activities. Therefore, when it comes to evaluating the impact of this type of intervention, it seems important to measure not only the autonomous and successful completion of tasks – as most previous studies did – but also to analyse off-task behaviours such as self-stimulation or stereotypical behaviours – which only a few studies have considered before (Mechling & Savidge, 2011) –, because these variables might play an important role in the activity performance success.

As a novelty, this study showed that using lights as prompts can be helpful for the embodiment of people with ASD in a real-world setting. During the activity performance, three participants required fewer educator prompts and all participants showed fewer off-task behaviours with the DT system with lights than with the TAU system. This finding may indicate that the light prompts helped them to shift their attention from the tablet towards the object affordances, allowing better physical interaction with the kitchen environment. One of the three participants who used the DT system with and without lights required fewer educator prompts and showed fewer off-task behaviours during the sessions in which he used the DT system with lights. The other two participants, however, showed no difference when using the DT system with and without the lights. This result could be explained by the fact that each person may respond differently to sensory stimuli (American Psychiatric Association, 2013; Bogdashina, 2003), some being more sensitive than others to light changes. Also, differences in sunlight intensity in the room due to the time of day or weather conditions may have played a role in this. Still, the use of lights may have resulted either neutral or positive, but in no case negative, compared to not using lights within the DT system.

One limitation of this study was that the number of sessions that participants had for some of the phases was scarce and even inexistent in the case of P4 for Phase B so no session with the DT system without lights could be tested for him. The explanation for this inequity was that the participants could not always attend the scheduled study sessions due to health issues, and additional sessions could not be conducted at a later stage because the study duration was limited. However, since the collected data points practically did not overlap across phases, the impact of the DT-mediated intervention compared to the TAU intervention could be observed. Another limitation was that generalisation and maintenance of the learning outcomes could not be assessed due to lack of resources. However, once this study was over, the DT system continued being used in the day centre and staff reported that it was increasingly beneficial for all participants.

4.1. Implications

This study aimed to cover important gaps which have been highly emphasised in the literature: (a) more efforts need to be addressed to promote autonomy and independence among people with ASD and ID (Jordan, 2013); (b) more intervention studies mediated by DTs should include not only children and adolescents but also adults with ASD to further explore the potential of DTs on this group; and (c) although in recent years the use of handheld devices to teach daily living skills has steadily increased, there is still need for more research on this topic (Kagohara et al., 2013). As a result, it is now known that four adults who were not *digital natives* (Prensky, 2001), and who were not familiarised with the use of DT on a regular basis (and one participant – P4 – even rejected its use in the past) could effectively interact with a DT system and that this helped them to better perform daily living skills. Therefore, future research should conduct more studies with DTs including adults with ASD to promote their autonomy and independence.

In this study, audio and picture prompting was chosen as the instructional technique for teaching daily living skills because the final purpose was to compare two different teaching methods (DT vs. non-DT) which were based on this technique. However, given that previous research has found video instruction to be effective at teaching daily living skills too, and the DT system used in this study – as well as many other commercially available applications – may allow for video instruction, it would be of interest for future studies to evaluate the impact of this other technique. A feature considered in this study, which has been previously measured by others (Mechling et al., 2009, 2010), was to give the participants the chance to self-adjust the number and level of digital prompts they needed to perform the activity. Providing adults with ASD and ID with a higher level of control in this regard may contribute to their learning and, as a result, to their autonomous and independent functioning. It is therefore recommended to make this possibility available to people who are learning with self-prompting techniques. Furthermore, off-task behaviours, which in many cases are responsible for failures in activity performance, may be considered when analysing the impact of future interventions.

The major novel contribution of this study has been to demonstrate that a handheld device connected to a lighting system has generally helped all of the participants and significantly helped one adult with ASD and ID to do laundry with fewer educator prompts and off-task behaviours. The combination of the audio and picture prompts delivered by the tablet and the light prompts – which were placed in strategic points of the kitchen to indicate the location where a given task had to be performed – may have helped the participants to off-load cognitive work onto the kitchen environment. This may be a potential DT system to support interaction and embodiment in the real world by encouraging people to look up from the screen of the tablet or smartphone and out into the possibilities offered by the physical environment that surrounds them. Hence, the use of lights as effective place indicators in structured learning environments and their impact on the activity performance of people with ASD should be further explored. Also, people's sensory response to light changes should be tested previously, and the use of a lux meter is recommended to keep sunlight intensity constant in future studies.

Part of the success of the results obtained in this study could be associated with the fact that some of the people who better know the participants (i.e., the educator and the Head of the day centre) were involved in the study. The information they provided on participant preferences, strengths, needs and behavioural difficulties was crucial to properly design individualised sessions. Also, the fact that the participants and the educator knew each other for long and the extensive experience she had teaching them, may have facilitated the implementation of the intervention sessions and, most probably, promoted the participants' learning. In addition, the fact that the study was conducted in the natural environment where participants used to learn and perform daily living skills may have contributed to the success of the intervention. Hence, as it is advised in guidelines to determine the strength of evidence-based practices in people with ASD (Reichow, Volkmar, & Cicchetti, 2008), it is highly recommended that future studies aimed at teaching daily living skills involve at least one person who knows the participant/s well and are conducted in real-world settings.

Finally, considering that people's happiness and wellbeing may rely on the development of daily living skills, and the fact that the whole community has identified the enhancement of these skills as a priority in ASD research (Pellicano et al., 2014), more efforts are needed in the line of this work.

Conflict of interest

The authors declare that they have no conflict of interest.

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