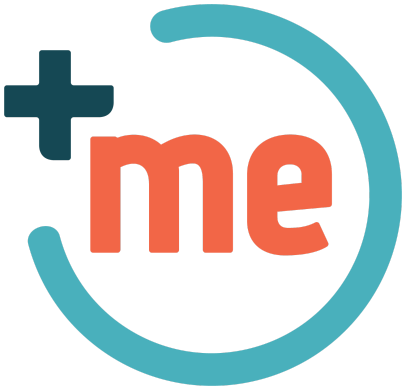

PlusMe: Transitional Wearable Companions for the therapy with children with Autism Spectrum Disorders

a European funded project

Deliverable 2.2

Experimental phase, stage two

Work Package 2 *Test*
due at month 21 (31st May 2022).

Lead beneficiary: CNR
Authors: F. Giocondo, N. Faedda[1], G. Cavalli[1], V. Sperati, B. Ozcan, F. Giovannone[1], C. Sogos[1], V. Guidetti[1], G. Baldassarre

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Project coordinator National Research Council of Italy,
Institute of Cognitive Sciences and Technologies, ISTC-CNR.

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1. Overview of the deliverable

This deliverable provides an update about the experimental activity concerning the *PlusMe* interactive toy. In more detail, the document presents the new, preliminary results obtained testing the device on 9 children diagnosed with Autism Spectrum Disorders (ASD).

The experimental protocol – the same described in the previous deliverable D2.1 *Experimental phase, stage one*[2]*,* presenting a pilot study involving 3 children, and reported in the document for the sake of completeness – aims to evaluate the *PlusMe* toy as a therapeutic supporting tool with a clear objective: to promote and increase the production of social interaction behaviour between child and therapist.

Moreover, as shown in the section 3, some intermediate results involving 5 children have been published in the short paper *Leveraging curiosity to encourage social interactions in children with Autism Spectrum Disorder: preliminary results using the interactive toy PlusMe,* presented at the international conference on Human-Computer Interaction, CHI '22; the paper (in attachment at the end of the current document) is provided as part of the deliverable.

The experiment, approved by the *CNR Research Ethic and Integrity Committee*[3], is carried out in close collaboration with the researchers from the Department of Human Neuroscience, University of Rome *Sapienza*.

2. Materials and methods

2.1. Participants

9 ASD children[4] attended the study, mean age 42 months, range 36-53 months. The acceptance criteria are based on a formal diagnosis of autism, based on standard DSM-5 criteria. The participants were recruited and tested at the Department of Human Neuroscience, Section of Child and Adolescent Neuropsychiatry, University of Rome La Sapienza. The children were denoted as high-functioning subjects, presenting a moderate level of symptoms according to the Autism Diagnostic Observation Schedule-2 (ADOS-2)[5].

[2] The deliverable D2.1 is available at the following link www.plusme-h2020.eu/deliverables/
[3] www.cnr.it/en/ethics
[4] This data includes the first 3 participants described in the deliverable 2.1.
[5] C. Lord, M. Rutter, P. C. Dilavore, S. Risi, K. Gotham, and S. L Bishop. 2012. (ADOS-2) Autism Diagnostic Observation Schedule, Second Edition. Western Psychological Services, Los Angeles.

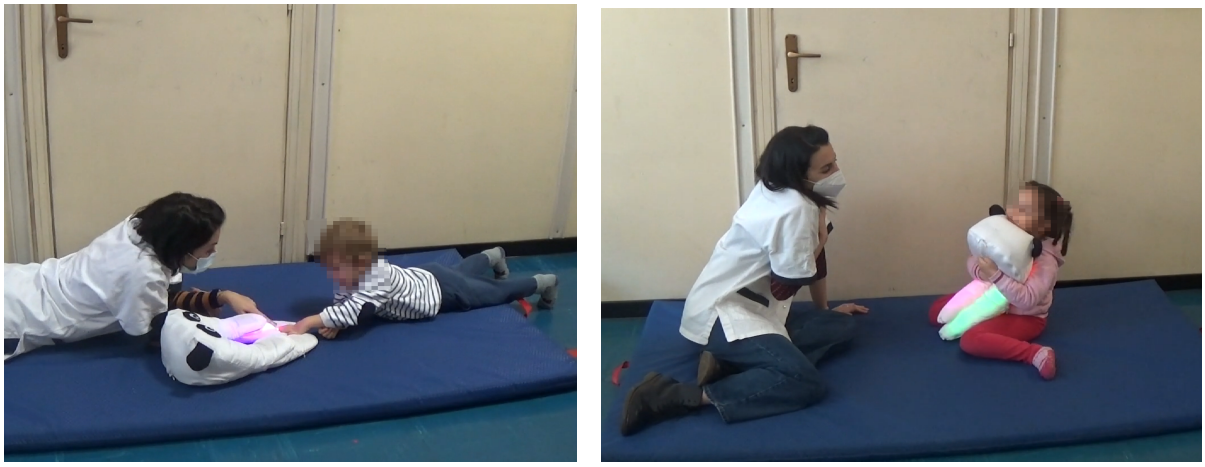

Figure 1. Images selected from the experimental sessions,
and showing the interaction between child, therapist and *PlusMe*.

2.2. Procedure

The experiment took place in an observation room where the distracting elements were removed (e.g., pens, notebooks and other toys). Each child was tested individually for four consecutive sessions, one per week, in the presence of two people: the neurodevelopmental therapist who played with the child using the *PlusMe* toy, and an experimenter in charge of managing the control tablet; the children did not know them before. During the experimental session, lasting around 10 minutes, the therapist proposed 5 different play activities (based on different *PlusMe* operating modes). The specific activities are here described in detail:

- ***exploratory activity***: each paw of *PlusMe* emits a different colour when it is touched. This activity is always the first one since it is useful to make the child familiarise with the toy and its multi-sensory feedback;
- ***whack a mole activity***: a random paw emits a blinking red light; if it is touched, a rewarding sound is emitted (trumpet notes) and the colour turns green. After a couple of seconds, the game restarts with another random paw.
- ***caress activity:*** if the child cuddles *PlusMe*, it emits a rewarding pattern (triggered by the experimenter through the control tablet);
- ***two hands activity***: if the upper paws are touched together; they light up in green and a brief sound is emitted (electronic ding);
- ***freedom activity***: the therapist asks the child his/her favourite *PlusMe* outcomes. The toy operating mode is then changed in real-time by the experimenter holding the tablet, based on the child's preferences, expressed by both verbal and non-verbal behaviour (namely a *social request*). In the absence of a child's request, the therapist proposes an output to the experimenter. Notably, the therapist actively encourages the child's social engagement: the verbal communication between the therapist and the experimenter is made explicit, to include the child in the triadic interaction, e.g., "What colour do you like, Tom (referred to child)? Did you hear (referred to the experimenter) what colour Tom desires to see? Let's set it up!". This activity is always the last one since it has to be

done when the child realises how the toy works and which rewarding outputs it can produce.

Each of the 5 activities relying on *PlusMe* were designed to stimulate attention, imitation, motor coordination, and promote explicit social requests (from child to therapist or experimenter) and create dynamics of joint attention.

Selected clips of the experimental sessions are available at the project website at the following link: www.plusme-h2020.eu/video/#ExperimentalSessionMayJune2021

2.3. Data collection

The experimental sessions were recorded with two cameras, and later analysed through a video-editing software. The *exploratory activity* was not taken into consideration for the data analysis. The clips were then rated to extract both duration (in seconds) and frequencies of 6 behavioural indexes related to social behaviour:

- ***imitation***: how many times the child correctly reproduces the therapist's behaviour on the toy during caress and two hands activities;
- ***watch therapist***: how long time the child looks at the therapist during all activities;
- ***smile*****:** how many times the child smiles at the therapist (all activities);
- ***watch PlusMe***: how long time the child looks at *PlusMe* (all activities);
- ***social request***: how many times the child asks the therapist or the experimenter —verbally or not— to change the rewarding pattern of *PlusMe* during freedom activity;
- ***sequences***: how many times the child looks first at the *PlusMe* and after the therapist (all activities).

In this deliverable only the following 3 indexes have been partially analysed: *watch therapist*; *watch PlusMe*; *social request*.

2.4. Preliminary results and discussion

The initial quantitative analysis of data shows a promising increment, during the 4 sessions, of the 3 indexes taken into account.

About the *watch therapist* index, the box plot in fig. 2 shows how some children spend more and more time looking at the therapist in all activities, especially during the first 3 sessions. This is an important observation given the poor eye contact behaviour evident in the participants, a key clinic symptom of ASD.

An interesting result is the *social request* index in the *freedom activity*, where the therapist encourages the child's engagement, asking him/her favourite *PlusMe* colour and sound. The bar chart in fig. 3 shows, for each session, the comparison between the requests made by the child (orange bars) and therapist (blue bars) towards the experimenter holding the tablet. In the first session, the therapist made more requests than the child, as shown by the clear unbalance between the bars in session 1. This trend changed in the second session: the two actors have

started playing together, being the child not passive as in session 1; importantly, the increment in the child's requests comes with a decrease of the therapist's request, an indication that a good balance is reached.

Finally, the box plot in fig. 4 shows how the *PlusMe* toy effectively captures the children's attention. This may mean that the different rewarding patterns of the *PlusMe* stimulate the child's curiosity and engagement.

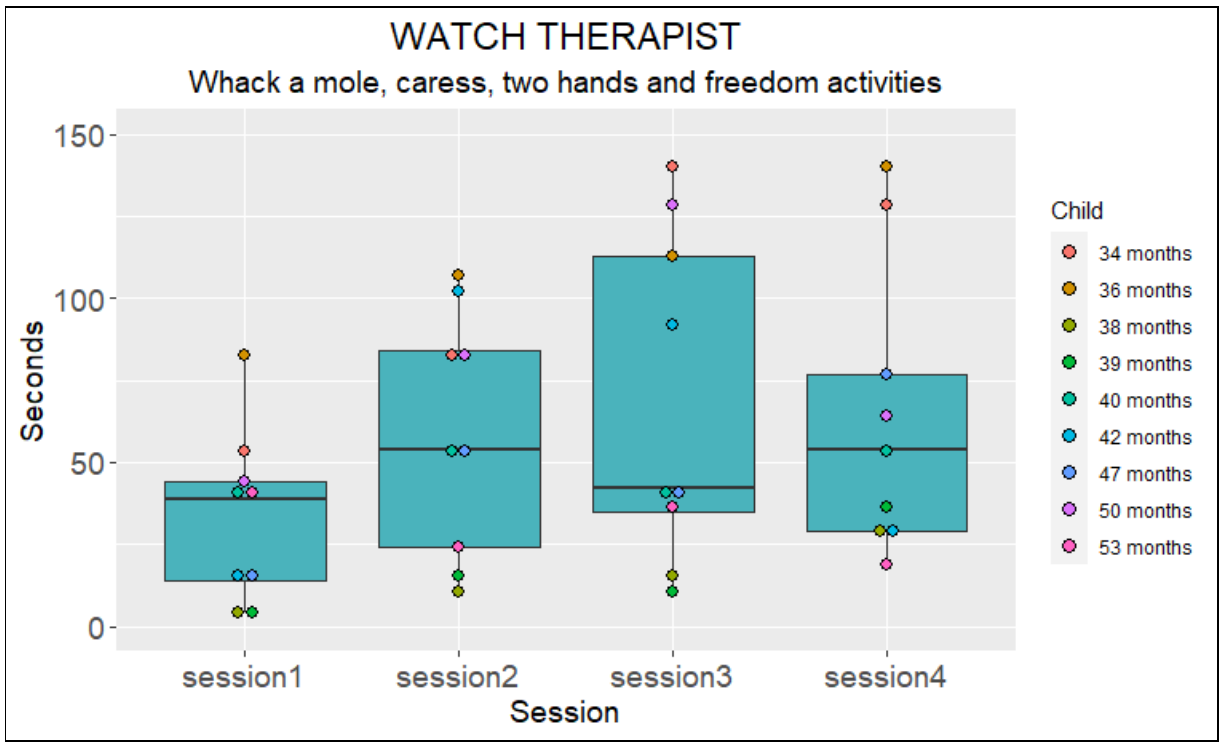

Figure 2. Box plot referred to the *watch therapist* index throughout the four sessions during all activities.

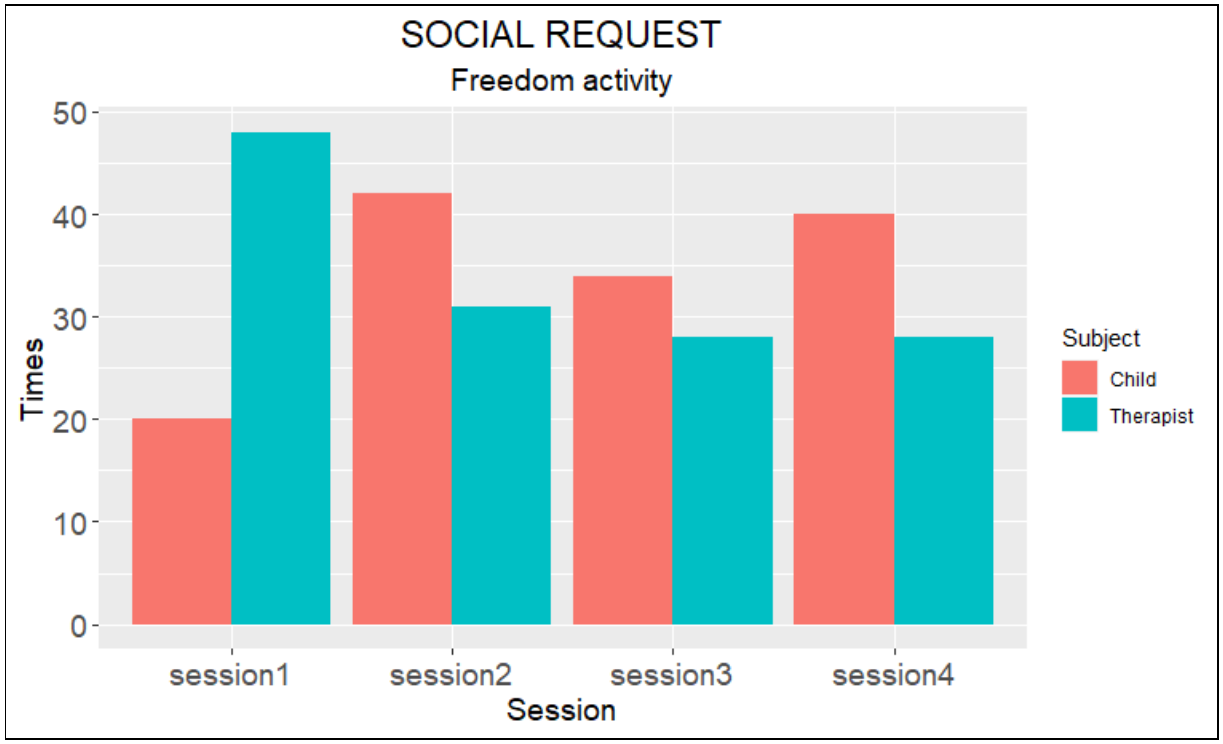

Figure 3. The number of social requests made by child and therapist throughout the four sessions, during the *freedom activity*.

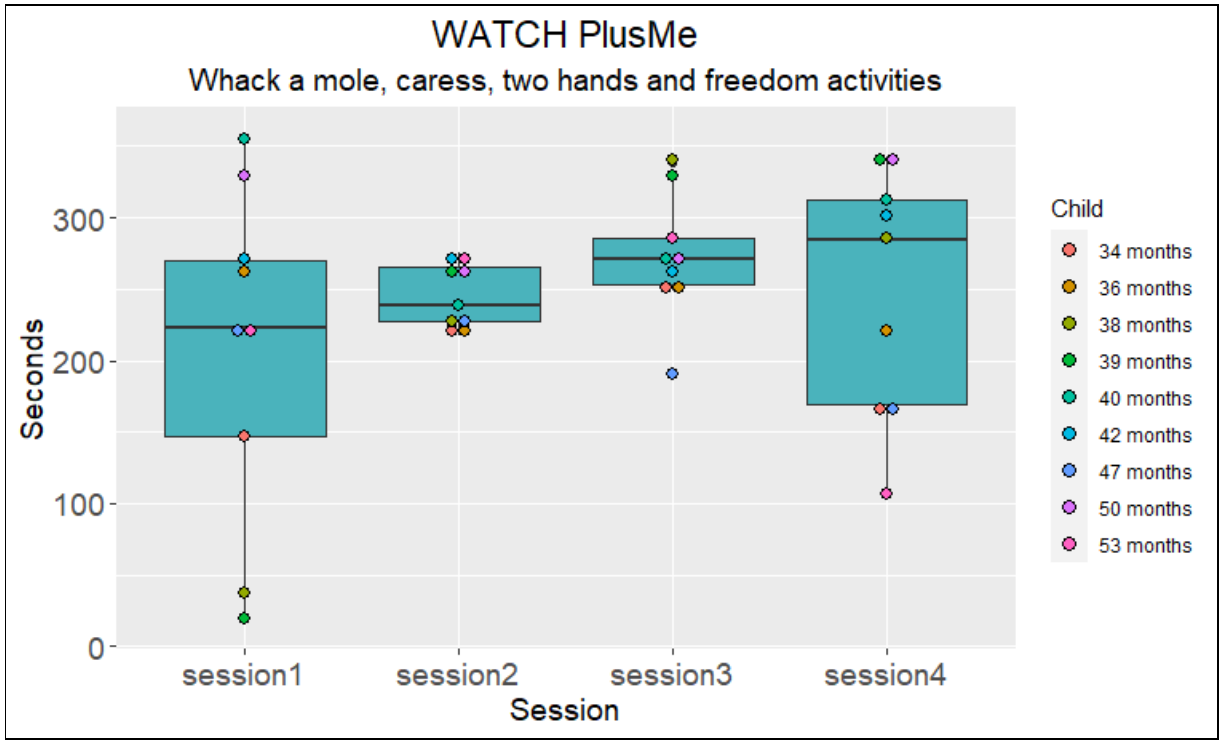

Figure 4. Box plot referred to *watch PlusMe* index during all activities, throughout the four sessions.

3. Presentation of data at “CHI’ 22”

Some intermediate results involving 5 children have been discussed in the short paper *Leveraging curiosity to encourage social interactions in children with Autism Spectrum Disorder: preliminary results using the interactive toy PlusMe,* presented in April-May 2022 at the international conference on Human-Computer Interaction, CHI ‘22[6].

The paper (attached at the end of the deliverable) is available at the ACM Digital Library website at the following link: https://dl.acm.org/doi/10.1145/3491101.3519716 (along with supplementary video material[7]), and is published as an Extended Abstract in the conference proceedings *CHI EA '22: CHI Conference on Human Factors in Computing Systems Extended Abstracts* (fig. 5).

Figure 5. The cover page of the CHI’ 22 conference proceedings.

[6] https://chi2022.acm.org/
[7] https://programs.sigchi.org/chi/2022/program/content/73289

4. Conclusion

We presented the preliminary observations about the use of *PlusMe* interactive toy as a potential support tool to encourage the social interaction behaviour in 9 high-functioning ASD children. The first results are promising, as several social indexes seem to show a moderate improvement during the 4 experimental sessions (especially between 1st and 3rd session).

A clear limitation of the study is the limited number of participants (N=9), along with the huge variability in the children's behaviour. In order to strengthen the statistics, the same experimental protocol will be tested on additional participants, with the goal to reach at least N=15 subjects.

Leveraging curiosity to encourage social interactions in children with Autism Spectrum Disorder: preliminary results using the interactive toy *PlusMe*

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Figure 1: The experimental soft toy *PlusMe* — the first prototype of *Transitional Wearable Companion* — used as a support tool to encourage social behavior in children diagnosed with Autism Spectrum Disorder.

ABSTRACT

Autism Spectrum Disorder (ASD) is a set of neurodevelopmental conditions, often characterised by important impairments in the social area. In the context of early intervention, we present preliminary results about the social behaviour of children with ASD using *PlusMe* as an experimental interactive toy, which is the first prototype of *Transitional Wearable Companions* concept. Specifically, *PlusMe* is designed to stimulate the children's curiosity and encourage behaviour on the basis of social interaction. The pilot test involved five high-functioning children, mean age 41 months, range 36-50 months. The participants were engaged in play activities together with the *PlusMe* toy and two researchers who aimed to encourage the children's social behaviour such as imitation and eye contact; the activities were repeated for four sessions (one per week). Although it is an ongoing study on a larger sample, the first data analysis is promising, preliminary observations seem to demonstrate that *PlusMe* can be used to improve some social behaviour such as eye contact, imitation, the interaction between two people.

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CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI)**; **Empirical studies in HCI**; **Interaction devices**.

KEYWORDS

ASD, autism, PlusMe toy, Transitional Wearable Companion, early intervention, therapy, social behaviour.

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1 INTRODUCTION

Autism Spectrum Disorder (ASD) is a set of neurodevelopmental conditions, generally evident from early childhood. People in the spectrum typically present – with varying degrees of severity – several life-long impairments including: limited or atypical social interaction, altered verbal and non-verbal communication, repetitive patterns of behavior, restricted interests or activities [2].

According to the World Health Organization, it is estimated that worldwide about 1 in 160 children has an ASD [1], even if recent reviews report higher estimations in developed countries (≈1 in 132 [3] and ≈1 in 67 [11]).

On average, a formal diagnosis of ASD is given in early infancy, around the age of five years [14]; nevertheless, warning signals (e.g., non-responsiveness to name, lack of spontaneous imitation, atypical play, over-focus and perseveration on objects instead of people, little or no eye contact) can be detected already in the first three years of life [8].

There is a general consensus that early intervention can have substantial benefits for children with developmental disorders [5, 12, 17]. Since the brain plasticity is particularly responsive during the 'sensitive' period of childhood, early treatments can positively affect the development of important neural pathways, crucial for the social behaviour [7], especially if initiated before the full onset of core ASD symptoms [21].

In this context, a growing interest is directed to the use of interactive technologies [20], robotics [4, 16] and mechatronic toys [13] as support tools to improve the social skills of ASD children. The efficacy of such instruments appears to rest on the clear attraction that most ASD children show toward mechanical and technological devices [9], which seem to generate a high degree of motivation and engagement [18].

In this Late-Breaking Work, we present the preliminary results about the use of the experimental interactive toy *PlusMe*, during four play sessions (one per week); during them, the toy is used *for the first time* as a potential therapy support tool to encourage the social interaction behaviour (e.g., eye contact and imitation) in five children diagnosed with high-functioning ASD, denoted with moderate level of symptoms. If *PlusMe* is an effective tool, it is expected that some social behaviour increase during the four sessions.

2 MATERIAL AND METHODS

2.1 *PlusMe* as an interactive toy

PlusMe is an experimental interactive soft toy, developed in collaboration with neurodevelopmental therapists (fig. 1). The shape, material and functionality are designed with the concept of *Transitional Wearable Companion – TWC* [15] which is a "smart" companion toy, neither too complex as a standard robot nor too simple as a teddy bear. A TWC features the following attributes: (i) it is able to arouse emotional attachment and reassuring feelings, thanks to the soft material and the wearability feature (common affective aspects in a *transitional object*); (ii) it can be perceived as a playmate, thanks to the nice animal shape; (iii) it can be used in simple sensory-motor games which can stimulate social competences (e.g., imitation, eye-contact), by leveraging the attractiveness of coloured lights and sounds, produced by an embedded electronics; (iv) given these attributes, it is easily usable by a caregiver.

Technically *PlusMe* is able to detect the human touch on its four paws by capacitive sensors, and to emit coloured lights and sounds (sensory-motor rewarding patterns) in response to that input, by embedded LEDs and speakers. By means of a *bluetooth* connected tablet (fig. 2), the caregiver can set different operating modes of the device, so that distinct sensory patterns can be produced. The operating modes let the caregiver select in real-time a given colour or sound in response to the child's request, or to set a particular game, featuring a more complex sensory-motor patterns[1].

It is important to note that the sensory-motor rewarding patterns of *PlusMe* depend on both the child (who touches the panda paws) and the adult caregiver (who sets the particular operating mode by the tablet, on the basis of the child's requests and reactions). In other words, the control of the toy is *shared* between the two actors. This means that the child has to communicate — verbally or not — with the adult to obtain a *desired* toy output, a feature that could encourage social engagement and joint attention.

The idea to use a transitional object as an *attentional anchor* to facilitate triadic interactions (i.e., interactions between two people, mediated by an object) in autism is discussed in [6].

In this pilot experiment, some of the available toy operating modes were used to set up play activities with the children; the operating modes are described in detail in the next section 2.2.

2.2 Participants and procedure

The pilot test was attended by five ASD children, mean age 41 months, range 36-50 months. The acceptance criteria are based on a formal diagnosis of autism, based on standard DSM-5 criteria [2], that was made after a complete neuropsychological evaluation at the Department of Human Neuroscience, Section of Child and Adolescent Neuropsychiatry, University of Rome *La Sapienza*. The children were denoted as high-functioning subjects, presenting a moderate level of symptoms according to the *Autism Diagnostic Observation Schedule-2 (ADOS-2)* [10]. The clinical observations are reported in Table 1. The participants were recruited and tested in the

[1] A demonstration video about the device features is available at www.plusme-h2020.eu/video/#PlusMe

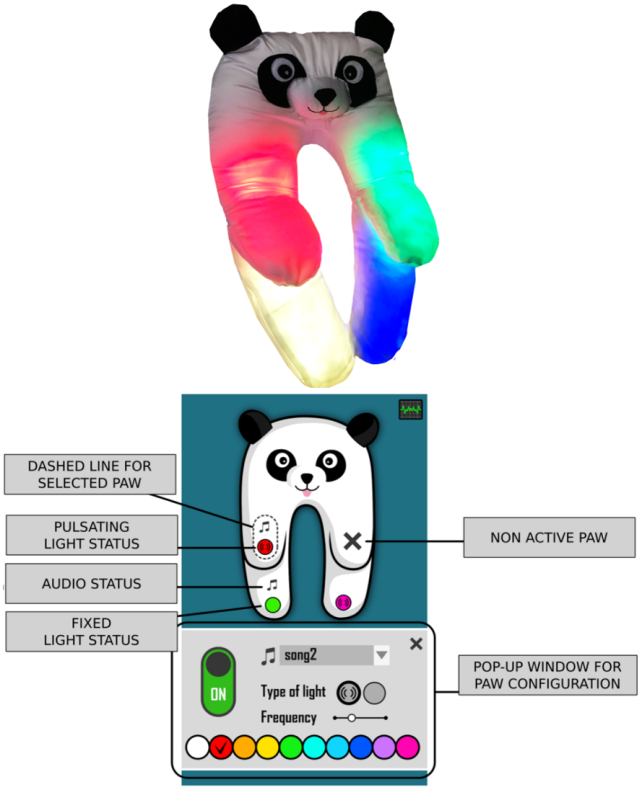

Figure 2: Through the App the caregiver can customize the outputs of the *PlusMe* toy, for example selecting a given color or sound.

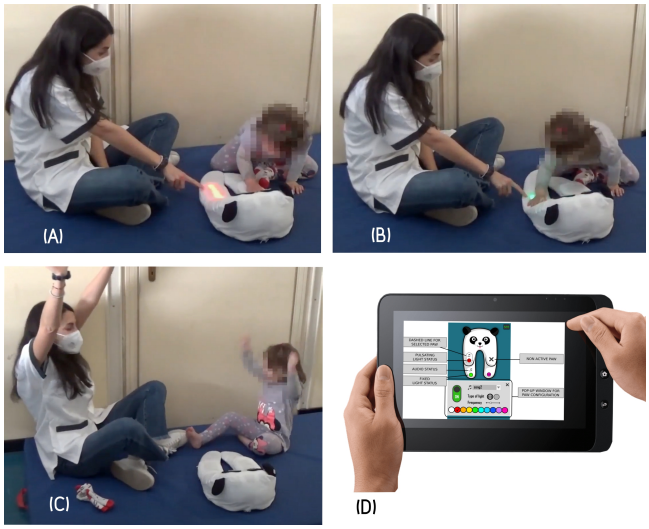

Figure 3: An example of the experimental setting. A) the therapist points to the red blinking panda's paw, during the *whack a mole activity*; B) the child touches the paw, which responses changing colour to green and emitting a brief song; C) child and therapist rejoice for the reward; D) the control tablet in the hand of the experimenter (in the same room).

same Department where they are subject to therapeutic activities. The Ethics Committee of the National Research Council of Italy approved the study (protocol No. 0052419/2021), and the parents gave written informed consent before starting the experiment.

The pilot test took place in an observation room where the distracting elements were removed (e.g., pens, notebooks and other toys). Each child was tested individually for four consecutive sessions, one per week, in the presence of two people: the neurodevelopmental therapist who played with the child using the *PlusMe* toy (which is always used), and an experimenter in charge of managing the control tablet (see fig. 3 for an example of experimental setting); children didn't know them before.

In the experimental session, lasting around 10 minutes, the therapist proposed five different play activities (based on different *PlusMe* operating modes) where the child was required to: (i) imitate the actions of the therapist; (ii) play with the therapist in a turn-taking game; (iii) make requests to change the colours and sounds of the toy. The therapist tried to involve the child in the play activities, stressing both verbal and non-verbal communication[2].

The specific activities are here described in detail:

(1) *exploratory* activity: each paw of *PlusMe* emits a different colour when it is touched. This activity is always the first one since it is useful to make the child familiarise with the toy and its multi-sensory feedback;
(2) *whack a mole* activity: a random paw emits a blinking red light; if it is touched, a rewarding sound is emitted (trumpet notes) and the colour turns to green. After a couple of seconds, the game restarts with another random paw. This activity is thought to stimulate the joint attention skill;
(3) *caress* activity: if the child cuddles *PlusMe*, it emits a rewarding pattern (triggered by the experimenter through the control tablet); this activity is designed to encourage emotional and imitation responses;
(4) *two hands* activity: if the upper paws are touched together, they light up in green and a brief sound is emitted (electronic ding). This activity is thought to stimulate attention, motor coordination and imitation ability;
(5) *freedom* activity: the therapist asks the child his/her favourite *PlusMe* outcomes. The toy operating mode is then changed in real-time by the experimenter holding the tablet, on the basis of the child's preferences, expressed by both verbal and non-verbal behaviour (namely a *request*). In absence of a child's request, the therapist proposes an output to the experimenter. Importantly, the therapist actively encourages the child's social engagement: the verbal communication between the therapist and the experimenter is made explicit, so as to include the child in the triadic interaction, e.g., "What color do you like, Tom (referred to child)? Did you hear (referred to the experimenter) what color Tom desires to see? Let's set it up!". This activity is always the last one since it has to be done when the child realised how the toy works and which rewarding outputs it can produce. The activity

[2]Selected clips about the sessions are available at www.plusme-h2020.eu/video/#ExperimentalSessionMayJune2021

Table 1: Clinical observations about participants

Age	Clinical observations
36 months	-inconsistent gaze -poor modulated use of eye contact to initiate and regulate social interaction -reduced integration of eye contact with other behaviors in social openings -presence of shared fun in the interaction
38 months	-poor modulated use of eye contact to initiate and regulate social interaction -joint attention behaviors are possible, albeit immature -presence of shared fun in the interaction
39 months	-poor modulated use of eye contact to initiate and regulate social interaction -reduced integration of eye contact with other behaviors in social openings -marked impairment of spontaneous onset of joint attention behaviors
42 months	-tendency to play alone -reduced integration of eye contact with other behaviors in social openings -presence of shared fun in the interaction -poor modulated use of eye contact to initiate and regulate social interaction
50 months	-tendency to play alone -presence of shared fun -poor modulated use of eye contact to initiate and regulate social interaction

is thought to promote explicit social requests (from child to therapist or experimenter) and create dynamics of joint attention.

2.3 Data collection

The experimental sessions were recorded with two cameras, and later analysed through a video-editing software. The *exploratory* activity was not taken into consideration for the data analysis. The clips were then rated to extract both duration (in seconds) and frequencies of six behavioural indexes related to social behaviour:

- *imitation*: how many times the child correctly reproduces the therapist's behavior on the toy during *caress* and *two hands* activities;
- *watch therapist*: how long time the child looks at the therapist during all activities;
- *smile*: how many times the child smiles at the therapist (all activities);
- *watch PlusMe*: how long time the child looks at *PlusMe* (all activities);
- *social request*: how many times the child asks the therapist or the experimenter —verbally or not— to change the rewarding pattern of *PlusMe* during *freedom* activity;
- *sequences*: how many times the child looks first the *PlusMe* and after the therapist (all activities).

Such indexes have been selected as they provide a general idea of the social interaction between child and therapist and about the child's interest in the toy.

2.4 Preliminary results and discussion

Preliminary quantitative analysis shows how — on average — an increment during the four sessions is detected in all social indexes.

The box plot in fig. 4 indicates how the participants' ability to correctly imitate the therapist's behaviour, during the *caress* and *two hands* activities, improves throughout the sessions. While in the first session only two children present a great score (higher than the median), in the fourth session the variance between the children decreases, and the average score increases for all participants. Qualitatively the children seem to pay more and more attention to the therapist's gestures to trigger the *PlusMe* rewarding pattern.

About the *watch therapist* index, the box plot in fig. 5 shows how some children spend more and more time looking at the therapist in all activities, especially during the first three sessions. This is an important observation given the poor eye contact behaviour evident in the participants (Table 1), a key clinic symptom of ASD.

The improvement in this visual behaviour is partially accompanied by a less evident increment in the *smile* index, as depicted in fig. 6. In this case, it is important to note that the tests were done during the Covid-19 pandemic, which forced the therapist to wear a protective mask. The small increment in the index could then be due to a child's initiative to smile, and not in response to a therapist's smile; this interpretation needs further investigation.

An important observation that seems to further confirm the increment of interaction between child and therapist is the growth of the *sequences* index, illustrated in fig. 7. As said, this index represents the alternation of child's gaze from *PlusMe* to therapist. Clinical observation of many ASD participants is the "presence of shared fun in the interaction" (Table 1). The increment in the

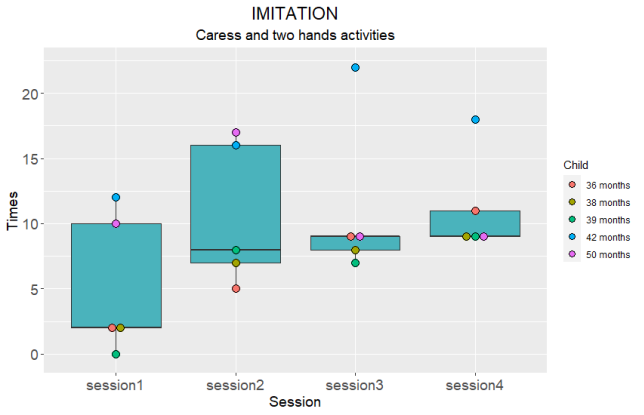

Figure 4: Box plot of the *imitation* index during the *caress* and *two hands* activities, throughout the four sessions. Each dot represents a child in accordance to Table 1.

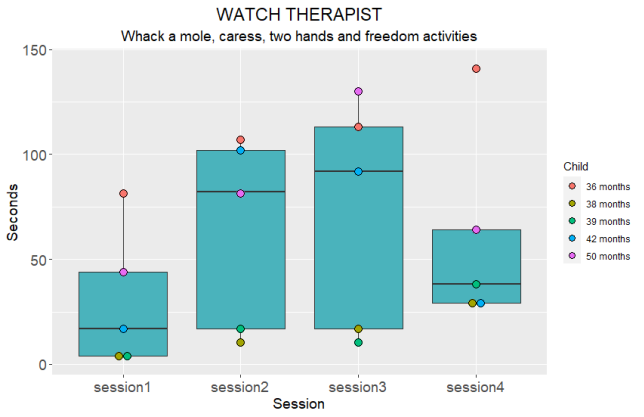

Figure 5: Box plot referred to *watch therapist* index during all activities, throughout the four sessions.

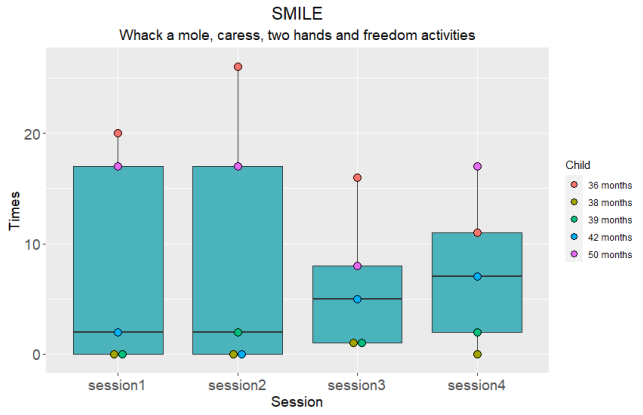

Figure 6: Box plot of the *smile* index during all the activities, throughout the four sessions.

Figure 7: Box plot referred to the number of times that child alternate the gaze from *PlusMe* to therapist.

sequences index can be a confirmation of the child's intention to share what happens on *PlusMe* with the therapist.

Another interesting result is about the trend of the *social request* index in the *freedom* activity, where the therapist encourages the child's engagement, asking him/her favourite *PlusMe* colour and sound. The bar chart in fig. 8 shows, for each session, the comparison between the requests made by the child (orange bars) and therapist (blue bars) towards the experimenter holding the tablet; interestingly, while in the first session there is a clear unbalance (most of the behaviour is carried out by the therapist), in the fourth session a good balance is reached, with a clear increment of the child's requests in presence of a decrease of therapist's requests.

Finally, the box plot in fig. 9 shows how the *PlusMe* toy is effective in capturing the children's attention. This may mean that the different rewarding patterns of the *PlusMe* stimulate the child's curiosity and engagement.

About the results, it is interesting to note there is a great behavioral difference between participants. Almost always, two participants (38 and 39 months) have a score below the median. Interestingly, this behavior may be due to the timing of recruitment: these two children have been tested when they just arrived at the Department, while the others others had been subject to about three months of therapeutic activity.

Since the experimental protocol is currently ongoing on additional participants, the next analysis will rely on more reliable statistics, which will help the researchers in the interpretation of results.

3 CONCLUSION AND FUTURE WORK

In this Late-Breaking Work, we presented the preliminary results about the use of *PlusMe* interactive toy as a potential support tool to encourage the social interaction behaviour in high-functioning ASD. *PlusMe* belongs to the category of *Transitional Wearable Companion*, a novel concept of interactive devices which could be helpful in ASD treatment. In respect to a previous pilot experiment on ASD

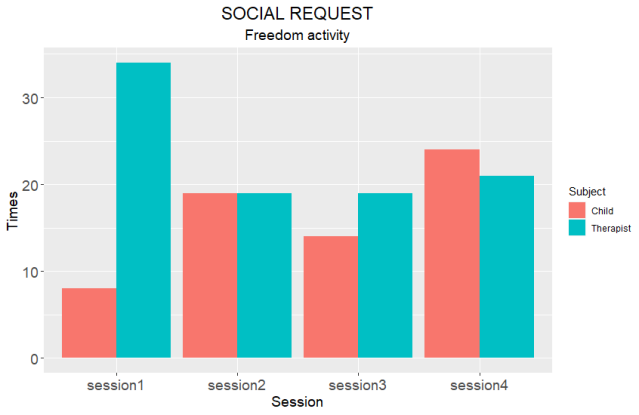

Figure 8: The number of social requests made by child and therapist throughout the four sessions, during the *freedom* activity.

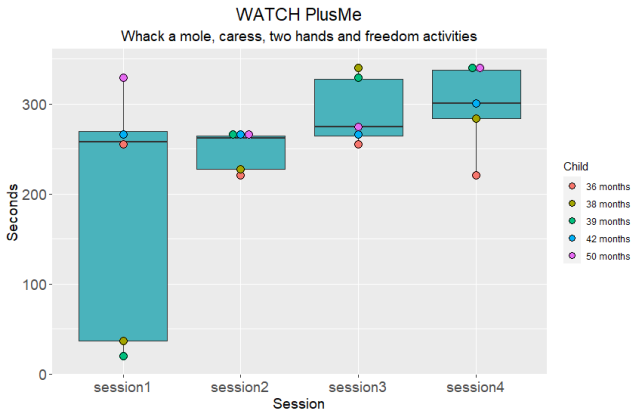

Figure 9: Box plot referred to *watch PlusMe* index during all activities, throughout the four sessions.

participants [19], it is the first time that the device is used in consecutive sessions, with the aim to improve social competencies and to improve general social engagement.

The results show that *PlusMe* is a promising support tool to enhance the child's social behaviors such as imitation, eye contact, social requests and smiles. Since these are all important aspects impaired or atypical in ASD, therefore early intervention to improve them can be an important key in early ASD therapy.

The described experiment is currently ongoing on a larger sample, to make the statistic analysis more reliable (we are aware indeed, that the current results consider the outliers). This will help both in the interpretation of results, and in the refining of the proposed playful activities.

From the engineering point of view, a new advanced version of the *PlusMe* is currently under process. The improvements concern both the hardware (e.g., additional sensory outputs as vibration motors on the paws), and the software (e.g., a new, more complete application for the control of the toy, and additional operating modalities for more complex activities). The new prototype will allow to set up more complex activities.

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