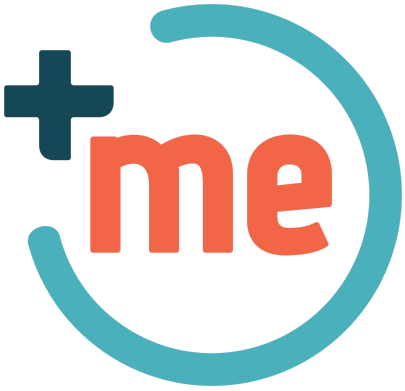

PlusMe: Transitional Wearable Companions for the therapy with children with Autism Spectrum Disorders

a European funded project

Deliverable 1.4

Final report on PlusMe device

Work Package 1 *Engineering*
due at month 21 (31th May 2022).

Lead beneficiary: CNR
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Institute of Cognitive Sciences and Technologies, ISTC-CNR.

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1. Overview of the deliverable

This deliverable reports the main features of the final *PlusMe* interactive toy, including details about the engineering process, and its status at the end of the *PlusMe* project (May 31th 2022). The document also reports and summarises some information contained in other related deliverables[4]:

- **D1.1** ***Identification of a research partner for engineering PlusMe***. It describes the *Institutes for Microelectronics and Microsystems*, IMM-CNR, a research institute part of the National Research Council of Italy (CNR, the same legal entity of the project coordinator ISTC-CNR), in charge to engineer the *PlusMe* prototype developed by ISTC-CNR;

- **D1.2** ***Engineering process of PlusMe***. It describes the engineering process of *PlusMe* device, including the development of a new, improved hardware and software;

- **D1.3** ***PlusMe product demonstrator***. It describes the novel features of the engineered *PlusMe* device;

- **D3.5** ***PlusMe production*** (from the related European project IM-TWIN[5]). It describes the initial small scale production of *PlusMe* (carried out by the engineering company *aTon srl* [6], under the supervision of IMM-CNR and ISTC-CNR) to promote the dissemination activities related to the use of the device by other users.

The new engineered *PlusMe* device presents several hardware and software improvements: it was developed according to industrial criteria (i.e., engineering of development process; use of standard schematics and electronic diagrams; production of standard blueprints, etc.), in order to progress from a *lab-prototype* (estimated[7] TRL 5) to a *close-to-market product* (estimated TRL 7).

2. *PlusMe* new design

The external appearance of *PlusMe* has been partially redesigned, and realised by a professional tailor, expert in the manufacture of soft teddy bears. For this purpose, a new textile – a mix of cotton and 10% elastane, certified *Standard 100 by Oeko-Tex*®[8] for safe use with

[4] These documents are available (when not confidential) at the following links: www.plusme-h2020.eu/deliverables/ and https://im-twin.eu/deliverables/
[5] https://im-twin.eu/
[6] www.aton-srl.it
[7] Technology Readiness Levels, TRL, https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-g-trl_en.pdf
[8] www.oeko-tex.com/en/our-standards/standard-100-by-oeko-tex

children – was also used; this textile is characterised by softness and elasticity, pleasing to human touch and more adapt for a soft toy. Interestingly, the flannel fabric texture nicely improves the diffusion of the LEDs coloured lights, an aesthetic feature very important for the final design (fig. 1).

Figure 1. *PlusMe* was partially redesigned to make it more like a professional teddy bear. The images show some examples of the nice coloured light diffusion.

3. *PlusMe* new technical features

3.1 Hardware

IMM-CNR developed and engineered the electronics supporting the toy functions (fig. 2 and 6). The new device is characterised by the following technical features:

- **Inputs:** the human touch is detected by invisible conductive patches, sewn underneath the external cotton fabric (the “Touch Pad Mesh, TPM” in fig. 2). The patches, as shown in figure 1, do not interfere with the light diffusion. The touch sensitive areas are placed on the 4 paws, the two ears, and the forehead;
- **Outputs**: the device is equipped with 3 types of outputs, to produce different sensory feedback for the user:
    - visual feedback: IMM-CNR developed 4 customised strips of addressable LEDs, which are embedded within the soft padding of the 4 paws (fig. 6);
    - auditory feedback: 2 mini-speakers are embedded within the Panda head;
    - haptic feedback: 6 vibrating motor mini-discs are embedded within the paws and the ears;

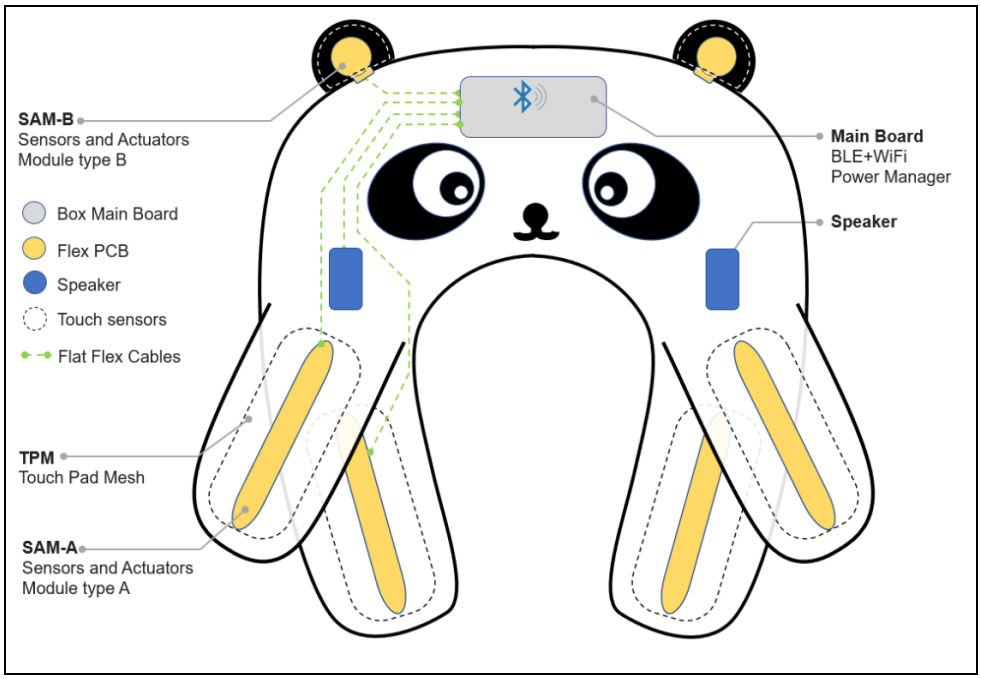

Figure 2. Simplified logic architecture of the new *PlusMe* device. Black and white dashed lines highlight touch-sensitive areas (TPM). The dotted green lines show the logical connections between the sensors and the Main Board.

- **Printed Circuit Board:** IMM-CNR developed a PCB hosting the main electronics (fig. 3). The Main Board is based on the ESP32, a microcontroller equipped with Bluetooth and WiFi connection, which easily integrates with the Arduino IDE[9] programming interface. The PCB is inserted and protected with a 3D printed custom box (fig. 4 and 5).

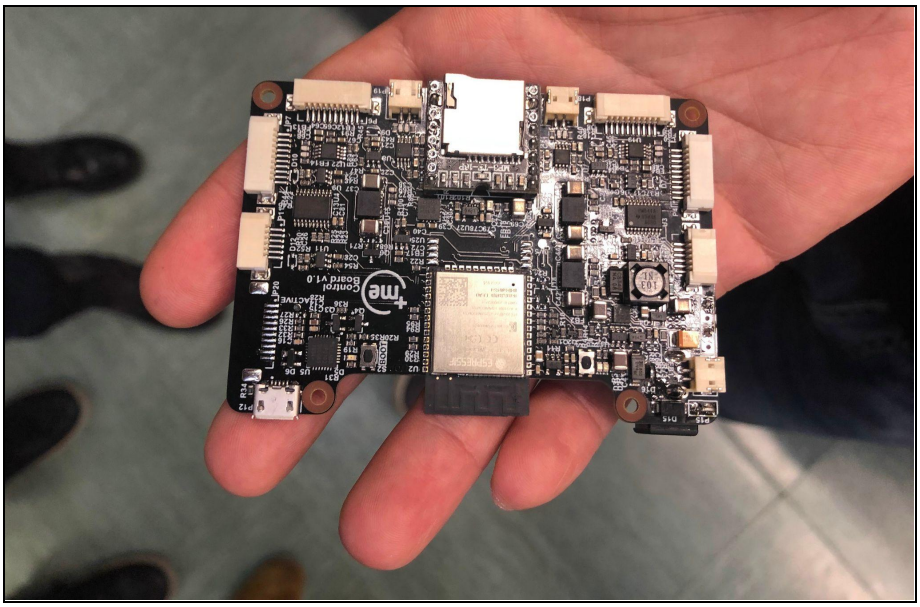

Figure 3. The Printed Circuit Board, PCB, realised by IMM-CNR, which hosts the main electronics of *PlusMe*.

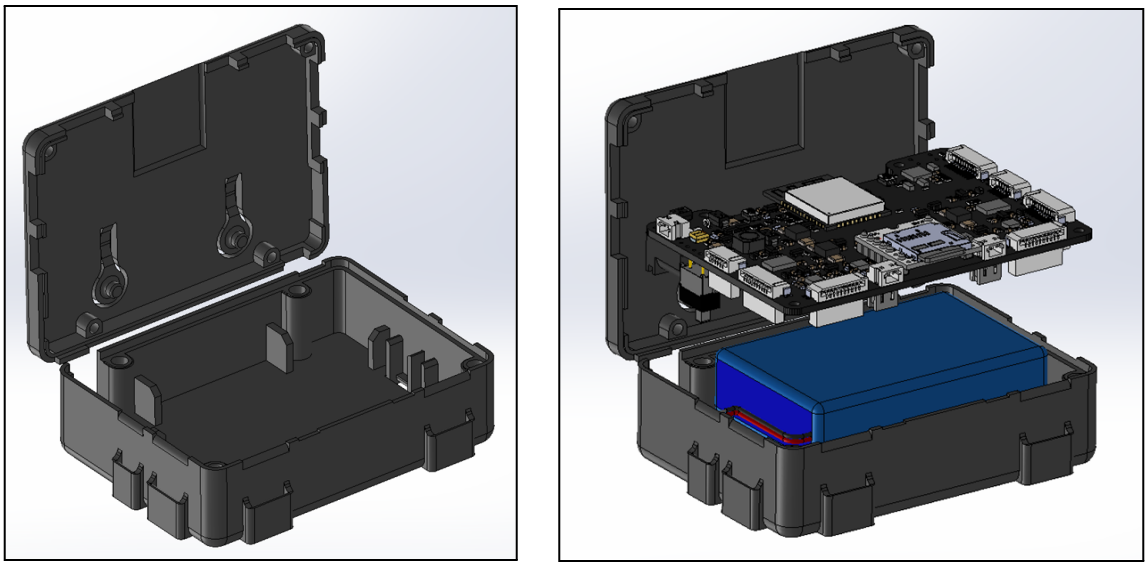

Figure 4. Inside view of the box for the Main board electronics, and exploded view of the Main Board assembly.

[9] https://www.arduino.cc/en/software

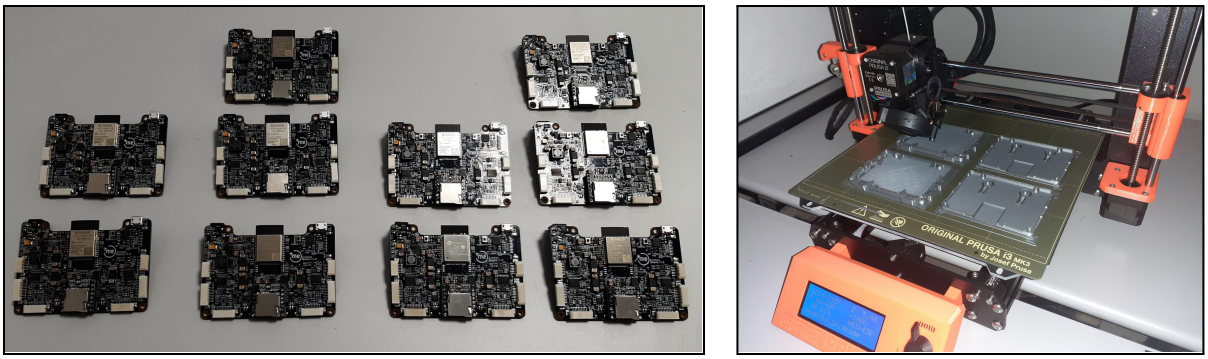

Figure 5. Left: the first 10 PCBs replicated and assembled by the company *aTon srl*. Right: the protection box, realised by ISTC-CNR with the 3D printer *Prusa i3 MK3S+*.

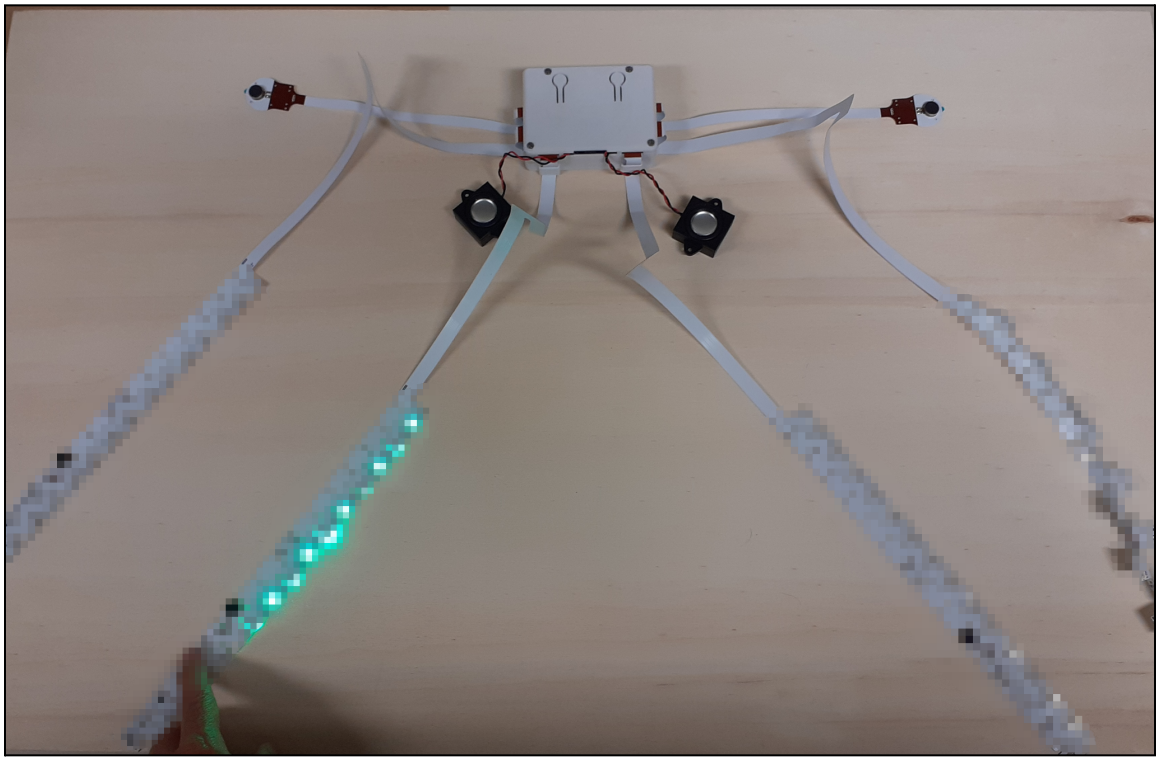

Figure 6. Left: the inner electronics before the final assembling within the Panda padding.

3.2 Software

ISTC-CNR developed a completely new control software, realised through an Android App developed with *Godot*[10], a free, open source 2D and 3D game engine. Interestingly, the ISTC-CNR researchers developed a general, previously missing Android plug-in[11], which enables a Godot-based App to connect and communicate with one or more Bluetooth Low Energy devices. The App GUI[12] was designed to be user-friendly, as it will be addressed mainly to neurodevelopmental therapists (fig. 7 and 8).

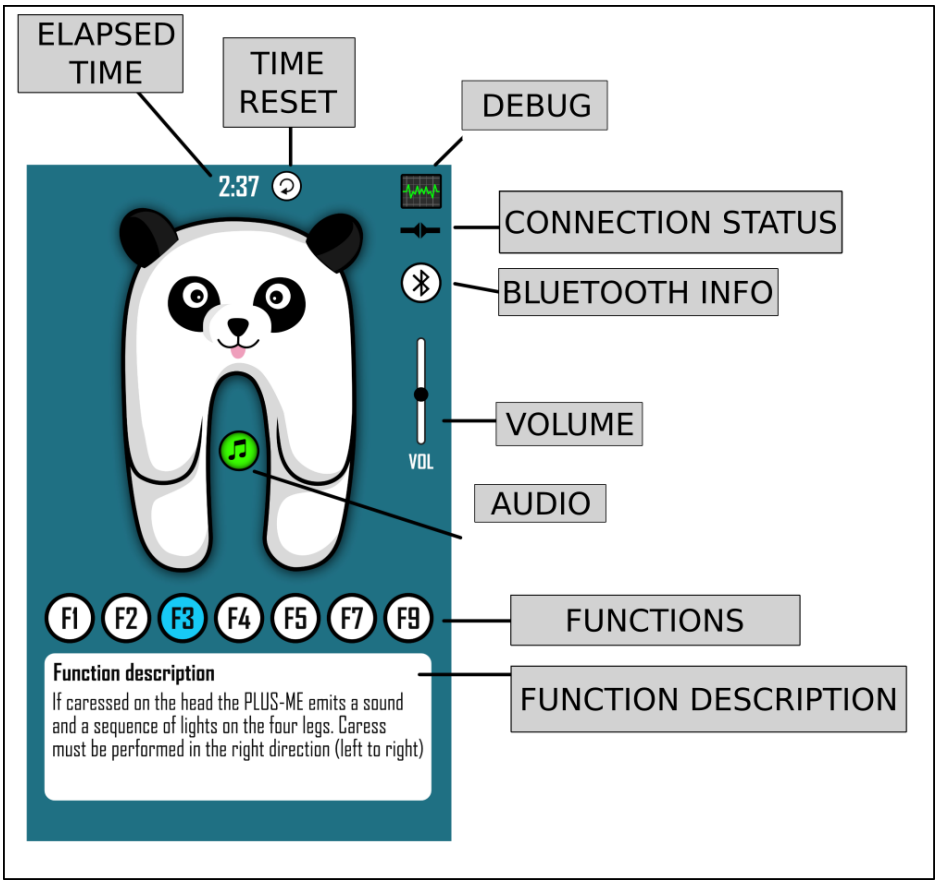

Figure 7. Screenshot of the App main GUI. Buttons and sliders allow the user to control the main features of *PlusMe* device. For example, the user can easily select the current function, namely the "game" to play with the child (Buttons F1 to F9 in the figure); each function[13] implements a particular input-output combination of input and outputs (coloured lights, sounds, vibrations).

[10] https://godotengine.org/
[11] The code is freely available at https://github.com/IM-TWIN/BLE-Android-Plugin
[12] Graphical User Interface
[13] At present there are 9 functions, but this set can be easily expanded to include novel "games".

Through intuitive buttons and sliders the user can easily manage the *PlusMe* behaviour and configure the operating mode; for example he/she can easily select the desired toy function (namely the "game" to play with the child), and/or configure the general aspect of the toy (e.g., the colour or sound the toy produces when the child's touch is detected).

Videos about the App are available at the dedicated webpage www.plusme-h2020.eu/video/.

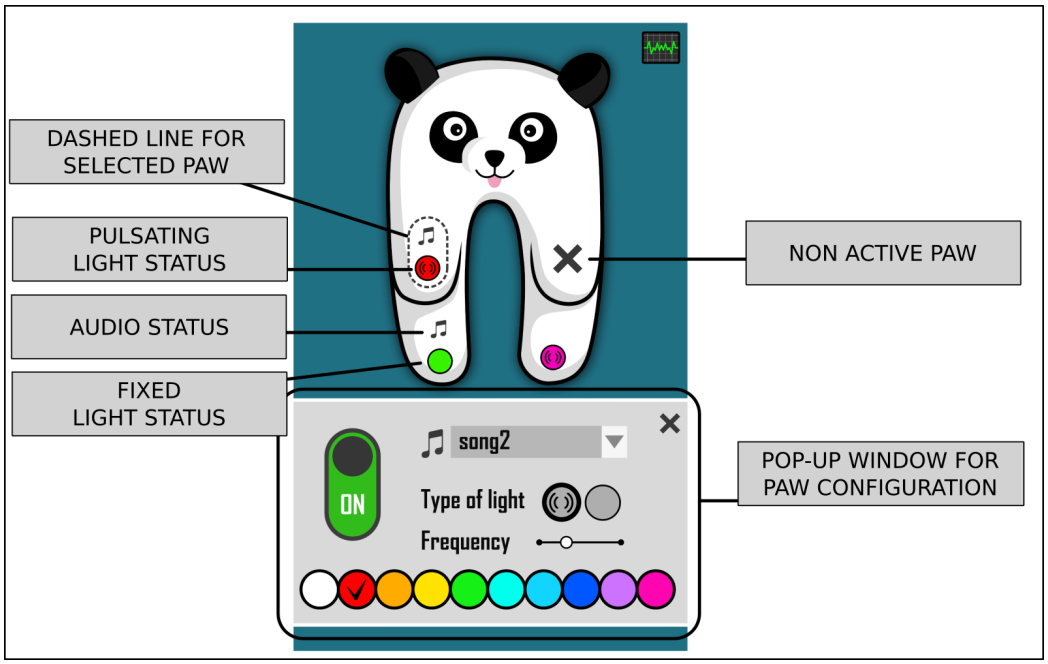

Figure 8. A subwindow of the GUI allows the user to customise several *PlusMe* features: for example, through a pop-up window the user can select the colour of the light, its temporal pattern (steady or pulsating) and the sound to be emitted when *PlusMe* detects a touch.

4. Presentations of the new prototype and awards

The new engineered prototype of *PlusMe* has been presented to the public in two international events:

- the *Milan Design Week 2022*, an important design exhibition hosted within the *Salone Internazionale del Mobile*[14], held in Milan on 6-12 June 2022. The participation was directly linked to the *Honourable Mention*[15] award, won by *PlusMe* interactive toy at *Design Intelligence Award-DIA*[16] contest, edition 2021 (fig. 9). DIA is the first international academic award in industrial design, established in 2015 by the *China*

[14] Milan Furniture Fair, www.salonemilano.it/en
[15] https://en.di-award.org/collections.html
[16] https://en.di-award.org/about.html

Academy of Art; the contest was created “to celebrate innovators and entrepreneurs' imagination and inventiveness”.

- the international conference *Interaction Design and Children-IDC’22*[17], held in Braga (Portugal), on 27-30 June 2022. The researchers showed to the audience the prototype features through the live demo *Interactive soft toys to support social engagement through sensory-motor plays in early intervention of kids with special needs*[18], during the dedicated session *Demo & Art*[19] (fig. 10).

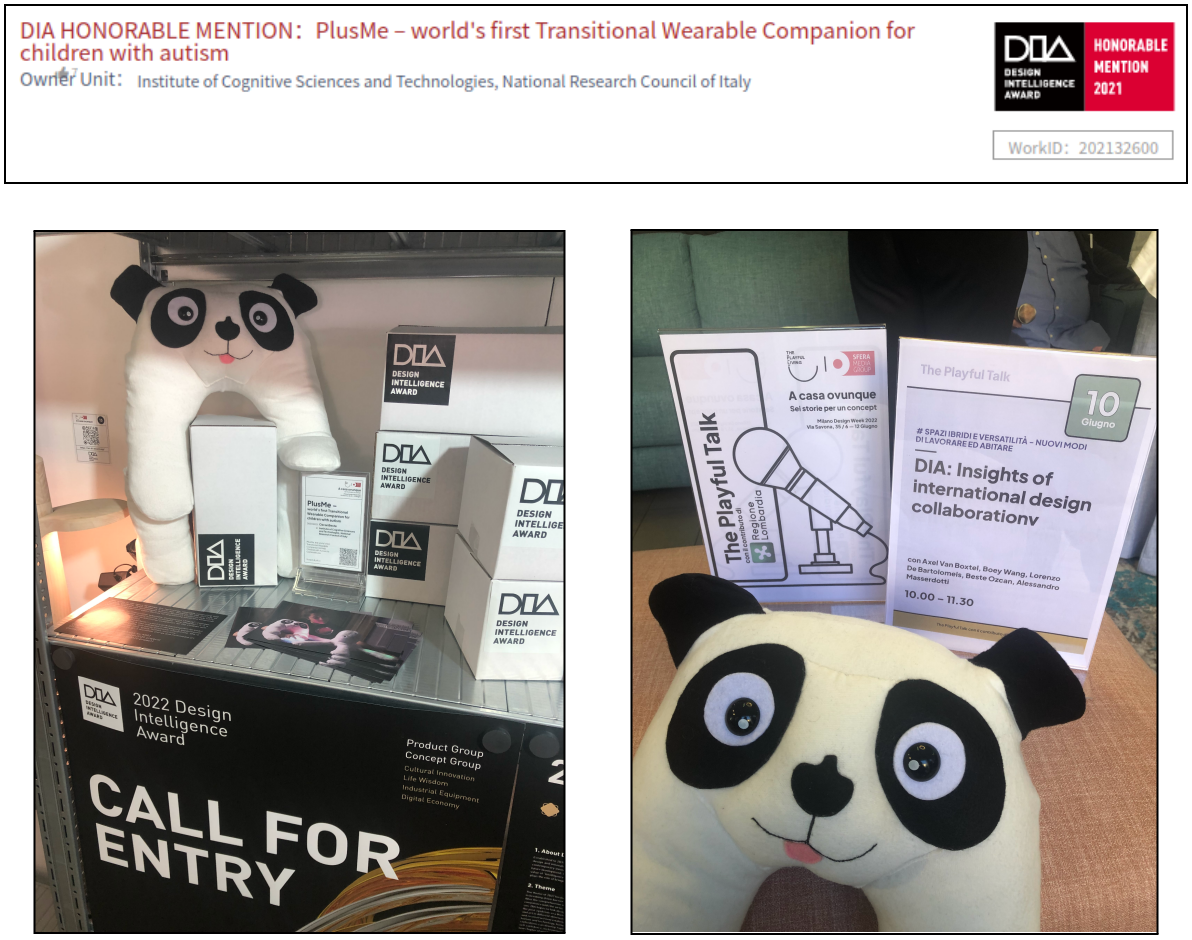

Figure 9. Top: the *PlusMe* got the *Honourable mention* at the *Design Intelligent Award*, DIA contest, 2021 edition. Bottom: thanks to the award, *PlusMe* was presented at the *Milan Design Week* 2022.

[17] https://idc.acm.org/2022/
[18] https://dl.acm.org/doi/10.1145/3501712.3535274
[19] https://idc.acm.org/2022/table-of-contents/

Figure 10. Top:the flyer for IDC'22 conference. Bottom: images of the conference and the *PlusMe* live demo, where the audience could test the *PlusMe* prototype.

Finally, during 2022, *PlusMe* will be also presented:

- at the *Joint International Conference on Digital Inclusion, Assistive Technology & Accessibility*, ICCHP-AAATE 2022[20], to be held on July 11-15 in Lecco (Italy), through a live demo[21];

- at the 10th European edition of the *Maker Faire*[22], a technological exhibition to be held in Rome on 7-9 October.

5. Conclusions

The dissemination, exploitation and clinical test about *PlusMe* will be carried on after the end of the project, in May 2022. These activities will be partially supported by the related European project IM-TWIN[23], which includes tasks concerning the further improvement and test of *PlusMe* device.

At present (July 2022), and thanks to the previous dissemination activity and the initial small scale production of the device, the ISTC-CNR signed formal collaboration agreements[24] with some clinical institutes and associations interested in testing *PlusMe*. These collaborations will be extremely useful to collect relevant feedback from the end-users (e.g., neurodevelopmental therapists; researchers in the field of developmental psychology; associations supporting ASD).

[20] https://icchp-aaate.org/

[21] www.icchp-aaate.org/content/plusme-transitional-wearable-companion-support-tool-encourage-social-emotional-engagement

[22] https://makerfairerome.eu/en

[23] www.im-twin.eu , GA 952095, https://im-twin.eu/eu-legal-information/

[24] see deliverable D2.3 *Diffusion of PlusMe to other Users*, https://www.plusme-h2020.eu/wp-content/uploads/2022/06/D2.3_diffusion_PlusMe_other_users.pdf