im twin

from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder

www.im-twin.eu

Project Technological Outcomes

- AUTISM SPECTRUM DISORDERS (ASD) THERAPISTS
- INTELLIGENT TOY INDUSTRY
- ASD THERAPY CENTRES
- MEDICAL DEVICE INDUSTRY
- DIGITAL HEALTH HARDWARE & SOFTWARE SMEs
- HEALTH, SOCIAL, EDUCATIONAL SERVICES
- ASD ASSOCIATIONS, POLICY MAKERS, CIVIL SOCIETY

IM-TWIN
TECHNOLOGICAL OUTCOMES

IM-TWIN is a European funded research project that aimed to develop new technologies to support the early treatment of children, aged between 30 and 48 months, diagnosed with Autism Spectrum Disorders (ASD).

The project acronym "IM-TWIN" stands for "from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder". The project lasted 36 months, from November 2020 to October 2023, and produced the following experimental tools:

1. Interactive soft toys, called Transitional Wearable Companions (TWC), specifically designed to stimulate the social competences (e.g., imitation, joint attention, eye contact) in ASD children and collect behavioral data during sensory motor play activities with the therapist.
2. A Sensorised T-Shirt, developed to collect physiological parameters (in particular ECG - Electrocardiogram, and EDA - Electrodermal activity) of ASD children during therapy, and obtain, through machine learning, an evaluation of their affective states, as positive, negative, and low engagement.
3. An Eye Contact Detection System, based on Camera Glasses (i.e. glasses embedding a micro camera) and a Computer Vision algorithm, allowing the detection of eye contact between child and therapist during the experimental sessions (eye contact is a relevant social cue in ASD).

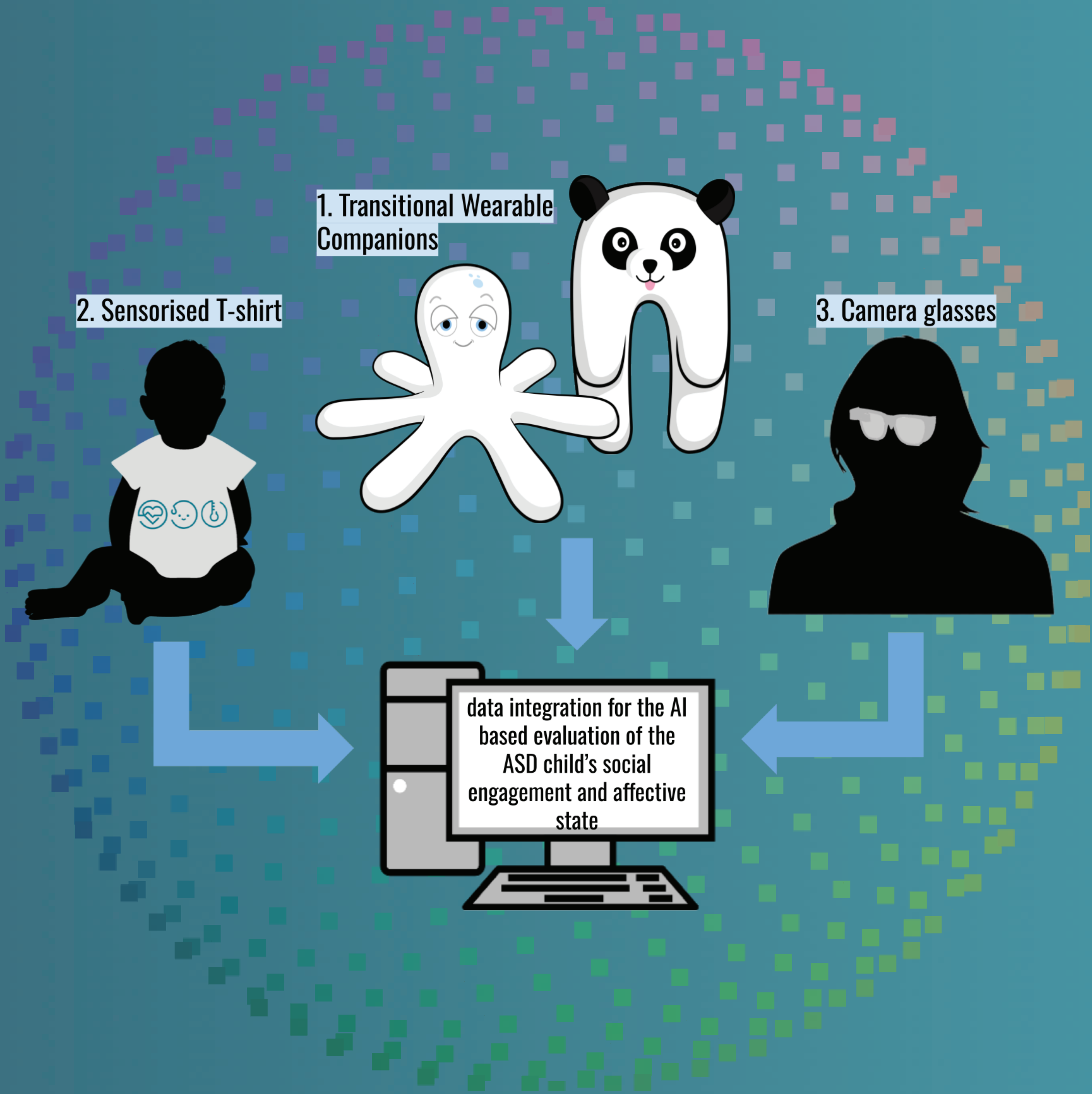
The 3 components, which are currently being tested with autistic and typically developed children, can be integrated in the "IM-TWIN system", a novel platform conceived to provide a general, objective evaluation of the social engagement between therapist and ASD children during therapeutic activities.

This work has received funding from the European Union's Horizon 2020 Research and Innovation program under grant agreement No. 952095 (project IM-TWIN: from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder).

European Innovation Council

Funded by the European Union

This brochure presents an overview of the 3 components and their possible interaction, to provide the reader with an overall impression of the complete IM-TWIN system and its potential use for research in the field of ASD and comparable Neurodevelopmental Disorders (NDD).



This brochure is mainly addressed to potential end-users and early adopters, such as neurodevelopmental therapists, child psychiatrists, researchers in the field of ASD and NDD, and people involved in ASD intervention.

See video of Technological Outcomes:
im-twin.eu/video/#project_final_technological_outcomes

1) Transitional Wearable Companions (TWCs)

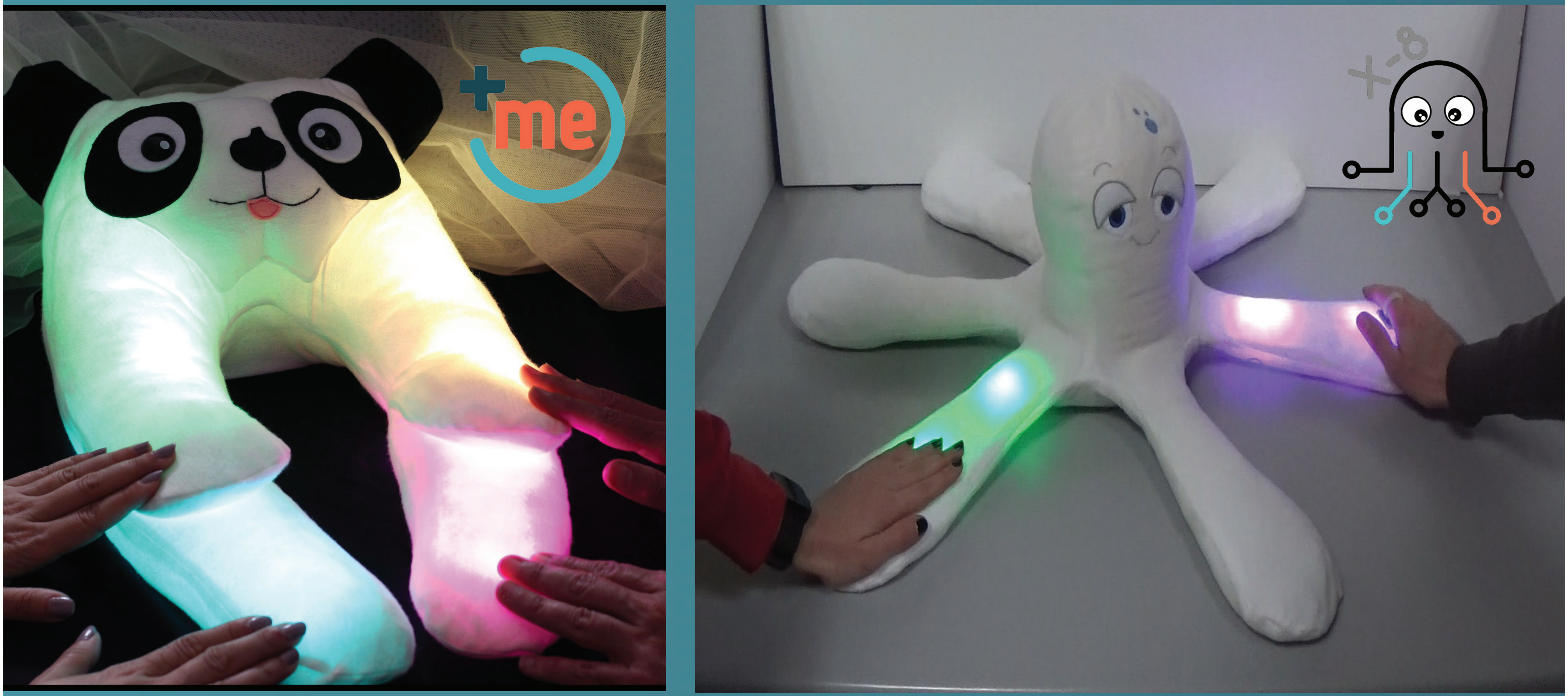


Fig. 1, Left: the TWCs Panda PlusMe, the first general purpose TWC; Right: Octopus X-8, a TWC, specifically designed to support turn-taking activities.

TWCs are soft interactive "smart" toys, animal shaped, equipped with sensors and sensorial actuators (coloured lights, speakers, vibrating mini discs) to provide visual, auditory and haptic feedback (Fig.1 and Fig. 2).

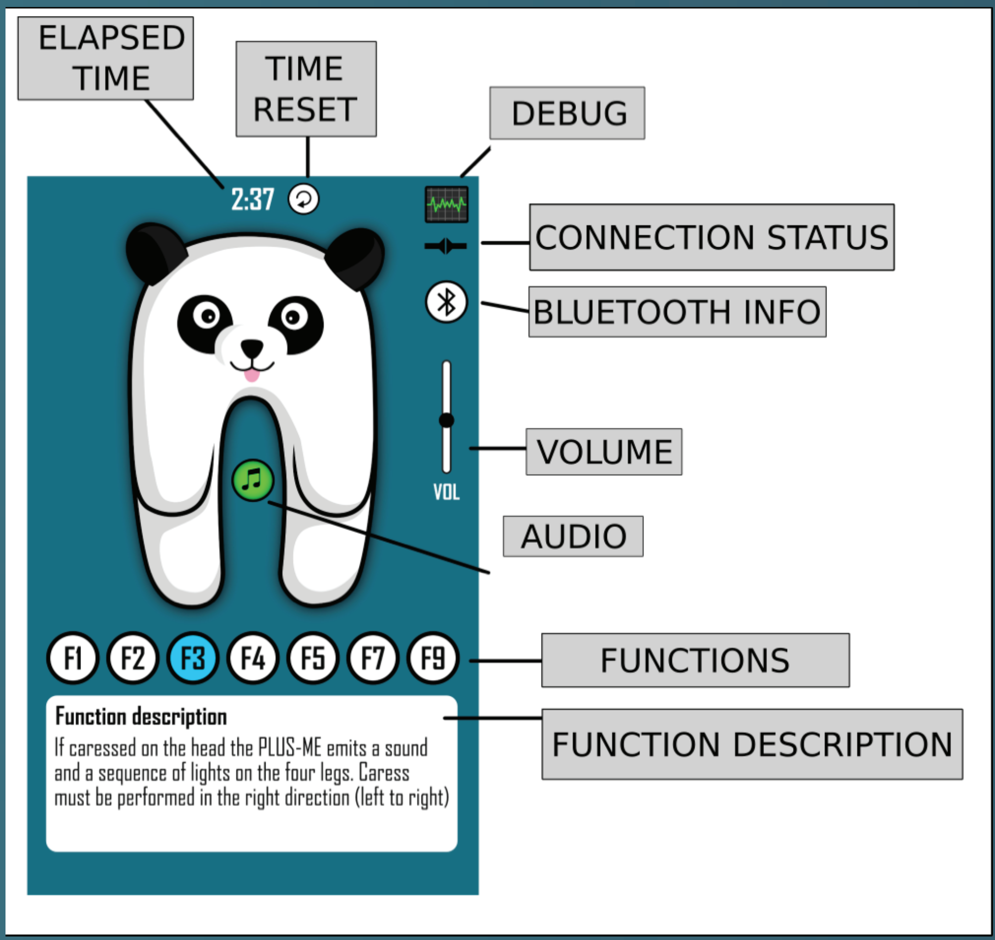
This type of output can be very attractive and motivating for kids and toddlers. Therapists can use the TWC to setup sensory-motor activities where the child is encouraged, through play and the toyes rewarding patterns, to socially interact with the caregiver.

Two prototypes of TWCs have been developed and improved* during the project: the *Panda PlusMe*, a general purpose TWC, and the *Octopus X-8*, specifically designed to support turn-taking games.

Fig. 2: From the design concept to prototype realisation.

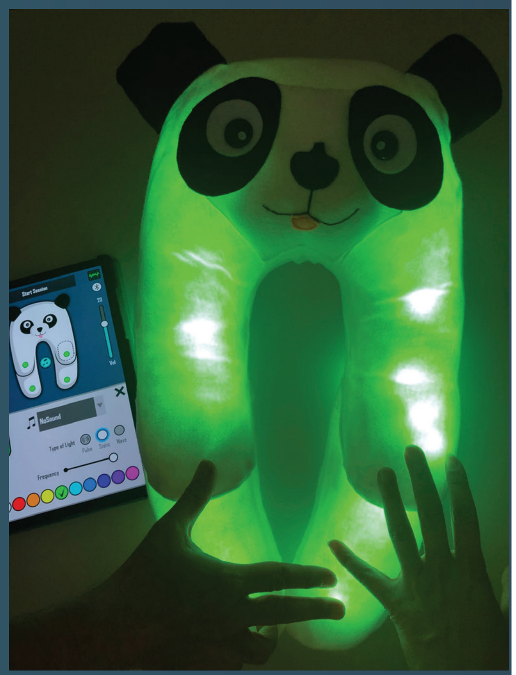
*The TWCs development has been partially supported by the European funded projects "PlusMe: Transitional Wearable Companions for the therapy of children with Autism Spectrum Disorders" (GA 945887, *www.plusme-h2020.eu/*) and "GOAL Robots: Goal based Open ended Autonomous Learning Robots" (GA 713010, *www.goal-robots.eu/*), and by the Italian funded project "+me: motivating children with ASD to communicate and socially interact through interactive wearable devices" (Progetto di Gruppo di Ricerca, L.R Lazio 13/08, *www.istc.cnr.it/en/content/me*).

One toy, multiple games



Bluetooth®

Bluetooth® Low Energy



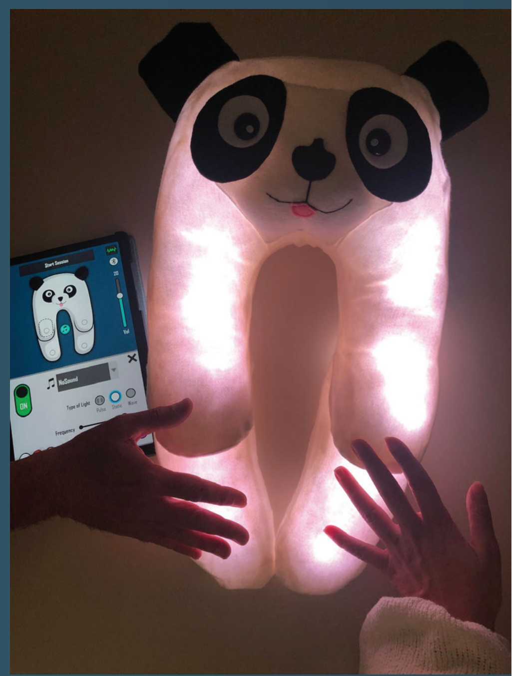


Fig. 3: Through the App, the caregiver can organise different play activities by customising the responses of the chosen TWC, selecting the child's favourite visual, auditory and haptic feedback.

The TWC toy is designed to be highly customisable. Through an Android, Bluetooth connected mobile App (Fig. 3), the caregiver, for example a therapist, can select among one of the available sensory-motor "games", conceived to encourage social skills such as imitation, joint attention, eye contact, social interaction, communication. In addition, the caregiver can "tune" the TWC rewarding patterns – e.g. a combination of coloured lights, amusing sounds and mild vibrations – according to the child's preference, so to provide gratifying, motivating sensory stimulation (Fig 4).

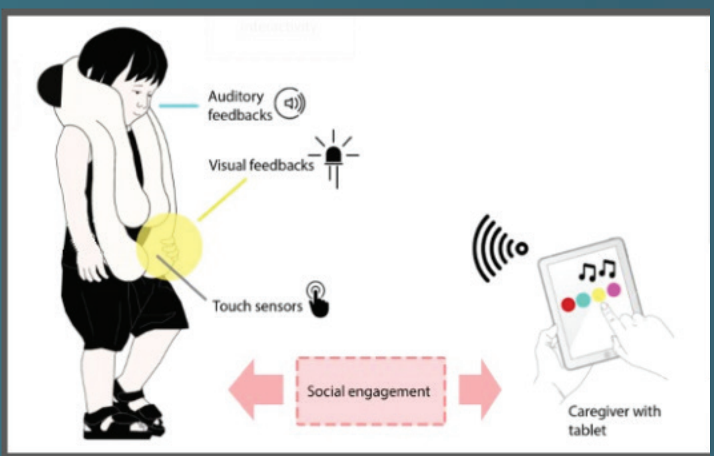


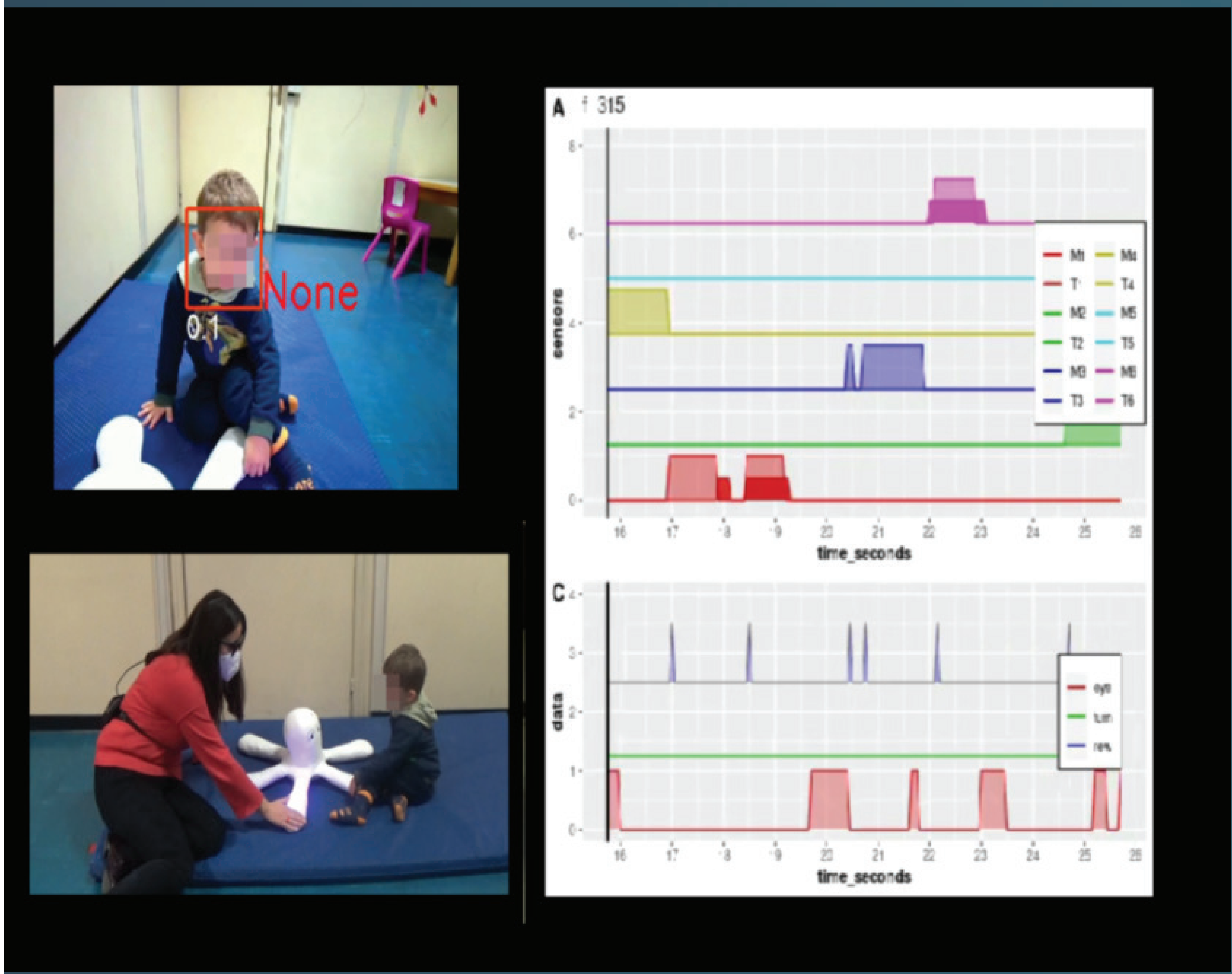
Fig. 4: TWCs are soft, and designed to allow a close, safe contact with the user.

See videos of Panda *PlusMe*:
im-twin.eu/video/#Plusme

See videos of Octopus *X-8*:
im-twin.eu/video/#x8_functional_features

See video about the control App:
www.plusme-h2020.eu/video/#The_new_control_App

A sensorised device for data collection



Data collected by TWC:

- When and who, between child and therapist, is touching the TWC paws.
- When and which reward pattern is triggered.
- Selected game among those available.
- Compliance with the selected game rules.

Fig. 5: The TWCs, thanks to their sensors, can produce data about the interaction of the child with the caregiver during the play activity. The data, displayed in the image as colored timeseries, is sent and saved in the control App as a log file that can be used for statistical processing.

Thanks to inner electronics, the TWCs can generate data about the users' interactions during the play activities (Fig. 5). User data is sent to the control App and saved in the form of a log file that can be analysed after the end of the experimental session. The log file contains several information, such as:

- Status (touched / not touched) of the touch sensors, including the user's identity (i.e. child or therapist);
- Triggering of a reward pattern (which visual/auditory/haptic combination pattern is triggered and when;
- Type of game selected (out of those available in the toy);
- The child's compliance with the rules of the game (e.g. during turn-taking games).

These data, once processed, can support an objective assessment of the play interaction between child and therapist, in particular concerning social interactions.

See videos about TWC data collection capabilities:
im-twin.eu/video/#x8_functional_features

Using TWCs with children

The TWCs are currently used in pilot experiments involving children aged 30-60 months, with ASD, other NDD (e.g. Communication Disorders and Rett Syndrome), and children with Typical Development (TD).
The results show how TWCs, thanks to the interactive features and the customisation properties, are enjoyable toys, able to stimulate good social engagement between child and caregiver (Fig. 6, 7, 8).

Fig. 6: The TWC Panda Plusme used as a support tool to stimulate the social engagement of ASD and TD children (pictures collected during tests run at the "Department of Human Neuroscience, Section Child Neuropsichiatry, University of Rome Sapienza", and at the "Learning Planet Institute").

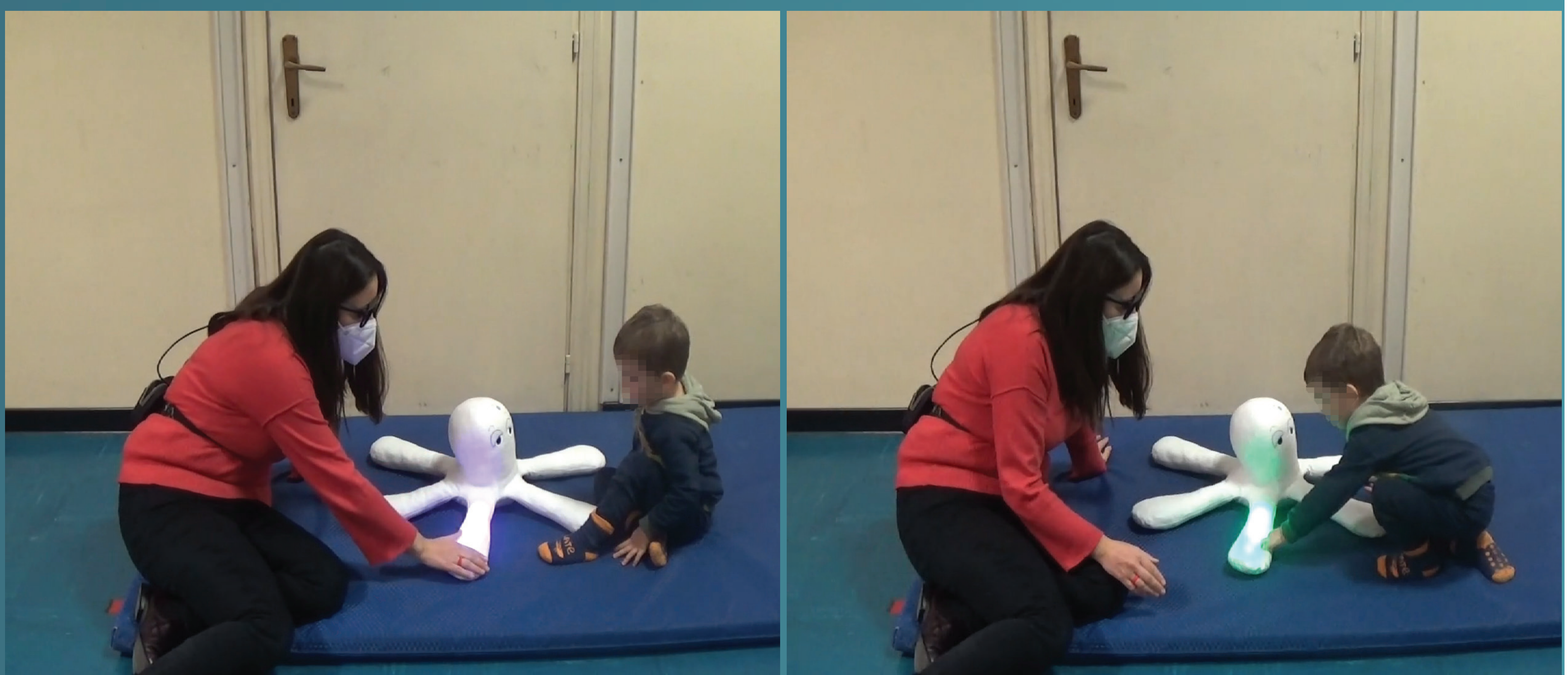


Fig. 7: The Octopus X-8 is a smart TWC: it is able to respond differently to child and caregiver's touch, e.g. by emitting different light patterns (in this picture: purple for the therapist and green for the child). This feature is used to implement games based on turn-taking rules.

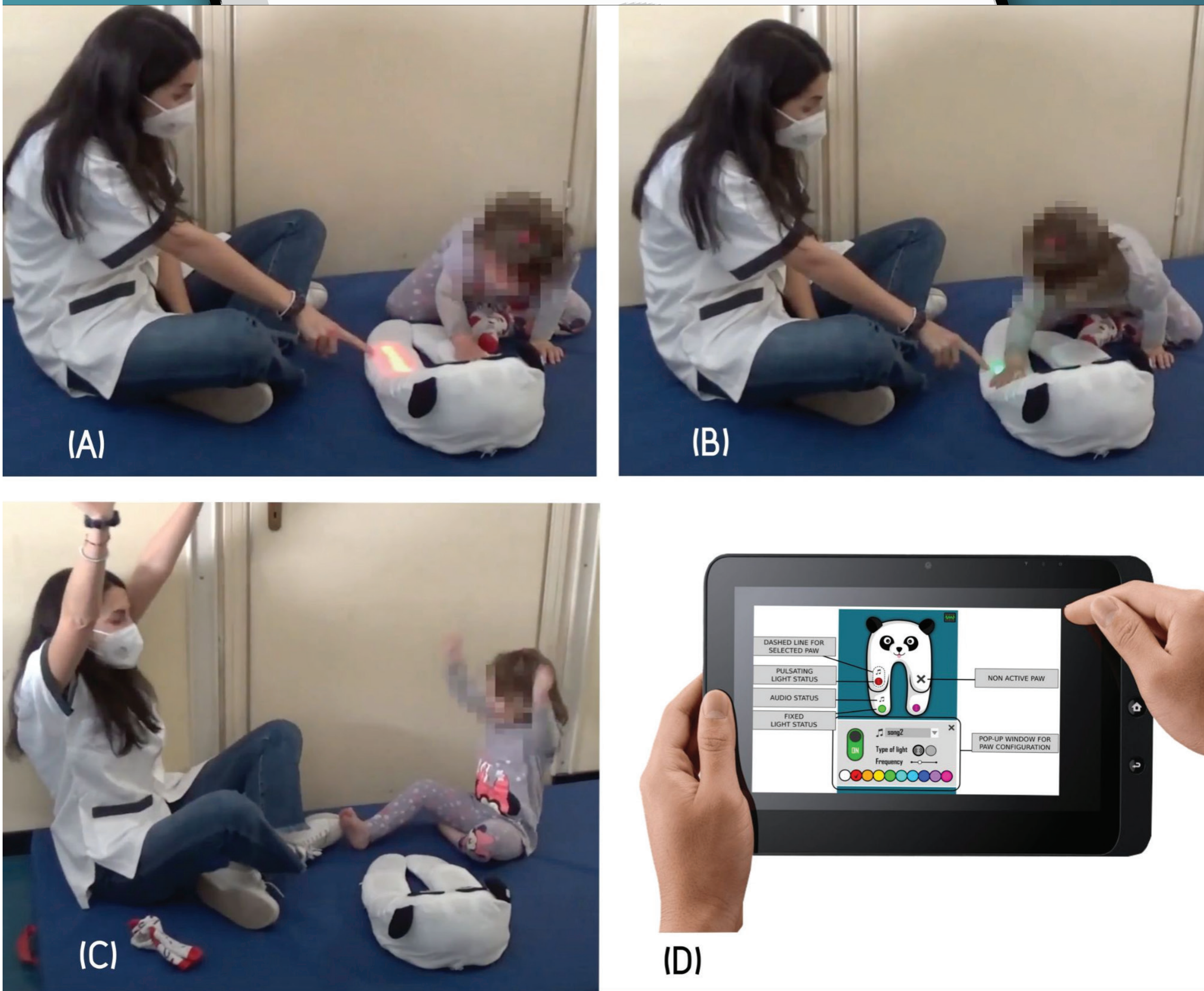


Fig. 8: A play sequence with Panda PlusMe, showing the shared fun between an ASD child and therapist.

See videos about experimental activities with TWcs and children:
im-twin.eu/video/#x8_functional_features

www.plusme-h2020.eu/video/#ExperimentalSessionMayJune2021

Novel electronic solutions embedded in TWCs

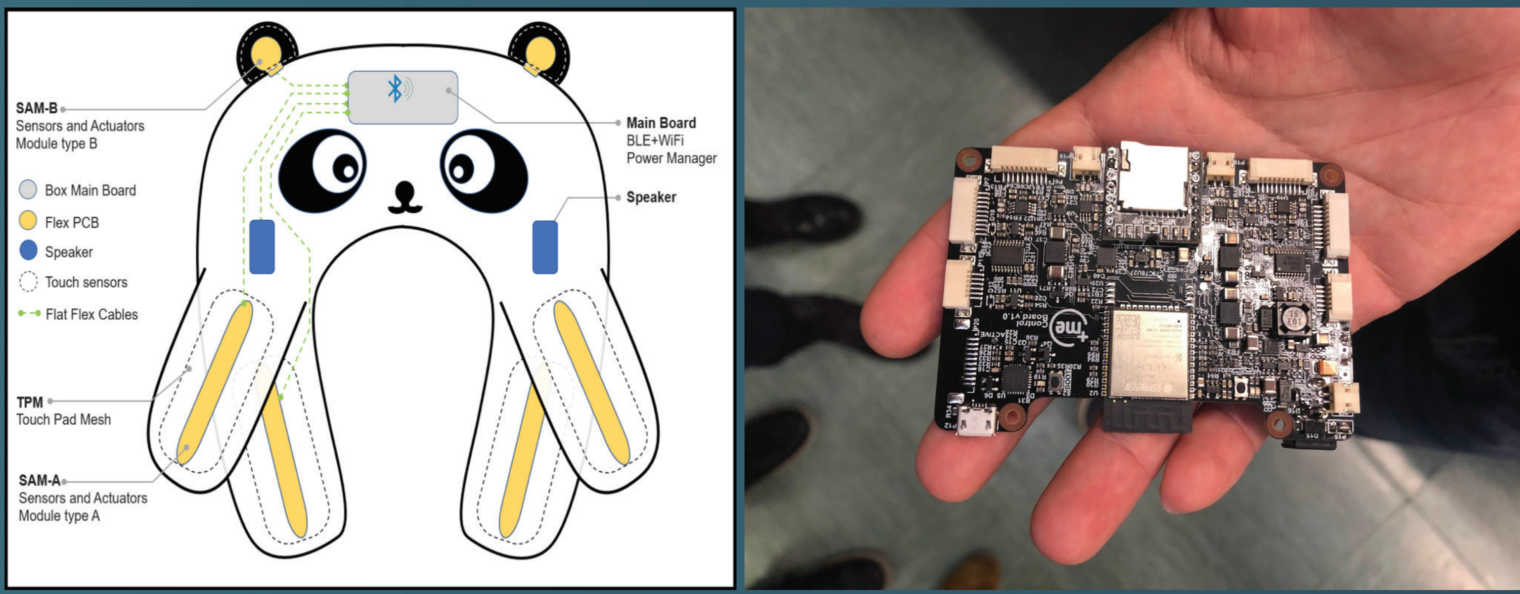


Figure 9: The whole electronics of TWC is embedded in the soft padding of the toy. Customised part, as the main Printed Circuit Board (PCB), have been developed for Panda PlusMe.

Customised electronics and novel solutions have been developed for the TWC Panda PlusMe (Fig. 9). In details the researchers realised flexible electronics, capable to withstand the mechanical stresses involved in children's play when electronics is embedded in a soft toy (Fig. 10, 11).

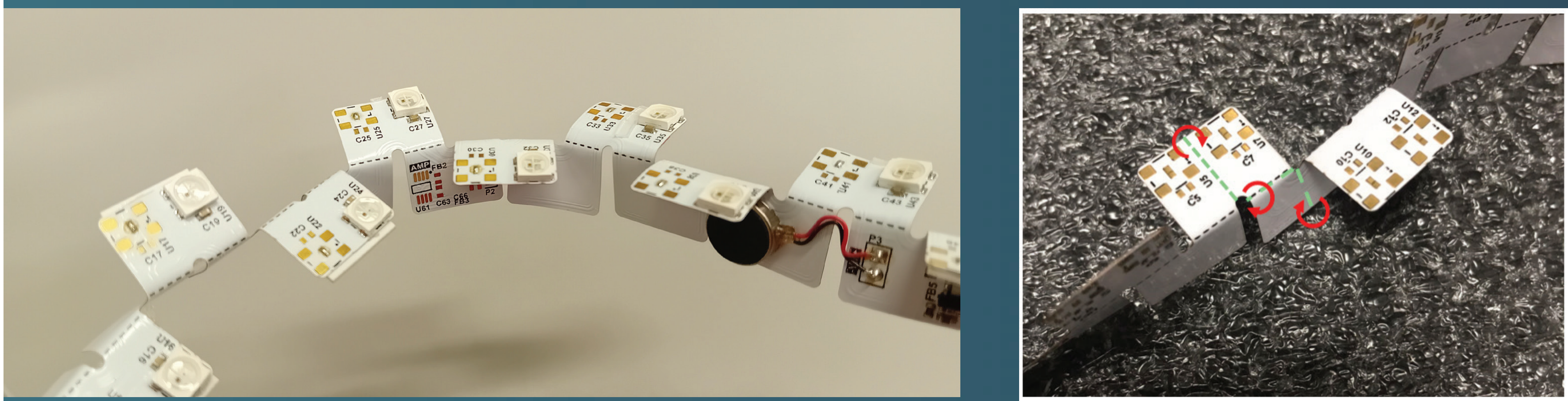


Fig.10: Flexible electronics embedding sensors (touch and IMU sensors) and actuators (RGB LEDs strips, vibrating mini discs, speakers), placed in Panda PlusMe paws. The design (under patenting) allows to withstand the mechanical stress in the 3 axes.

See the deliverables about the development of electronics,related software, and Panda PlusMe small scale production:

1) www.plusme-h2020.eu/wp-content/uploads/2021/12/D1.3_plusme_product_demonstrator.pdf

2) www.plusme-h2020.eu/wp-content/uploads/2022/07/D1.4_final_report_PlusMe_device.pdf

3) im-twin.eu/wp-content/uploads/2022/11/DELIVERABLE_D3.6_PlusMe_production_2.pdf

1 *2* *3*

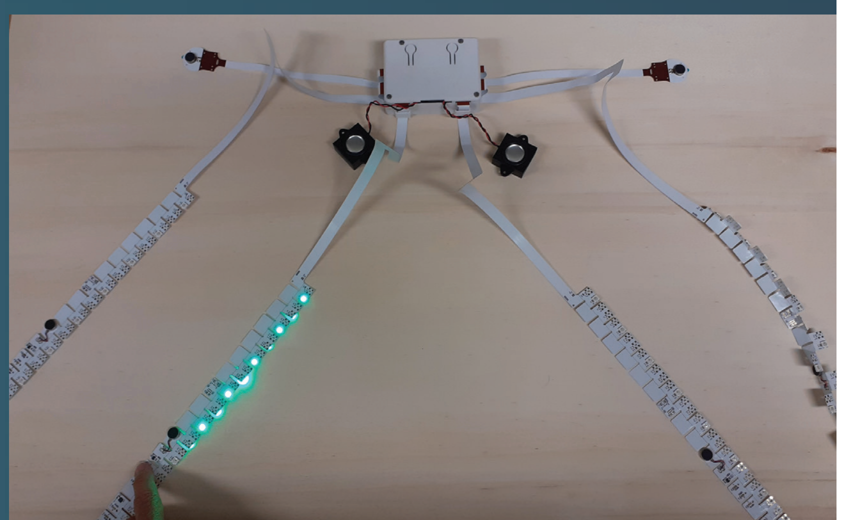


Fig. 11: The whole electronics assembled and ready to be embedded in the Panda PlusMe.

2) Sensorised T-Shirt

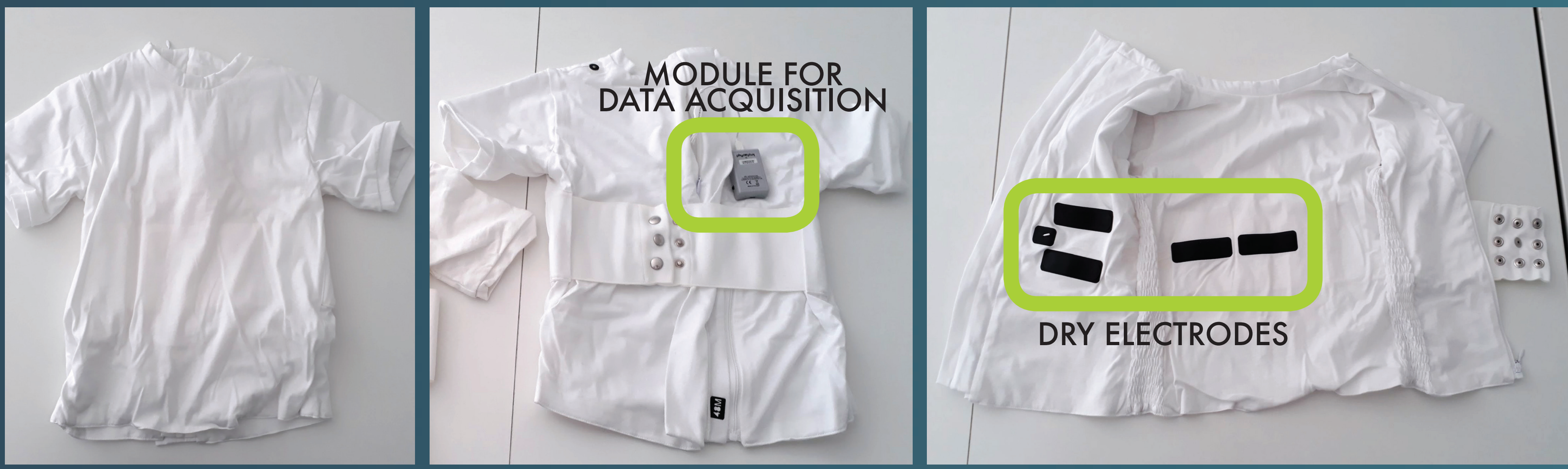


Fig. 12: Front, back and inner view of the sensorised t-shirt. Dry electrodes, which do not require gel to work, have been chosen to ensure the maximum comfort of the child.

A Sensorised t-shirt was specifically developed to collect physiological data in very young ASD children, aged 24-48 months (Fig. 12). The clothing is equipped with several sensors:

- Electrodermal activity (EDA) sensor, which measures the galvanic skin response, a physiological parameter related to the physiological and psychological arousal;
- Electrocardiogram (ECG) sensor, to measure the Heart Rate and Heart Rate Variability, two parameters related to the stress level;
- Skin temperature (ST) sensor, to detect body temperature
- A 9-axis Inertial Measurement Unit (IMU) sensor, used fo;r body motion tracking.

Children at play move a lot, so the choice and arrangement of sensors, and the textile tightness and elasticity, were chosen to ensure the maximum contact between skin and sensors, and hence reliable data (Fig. 13).

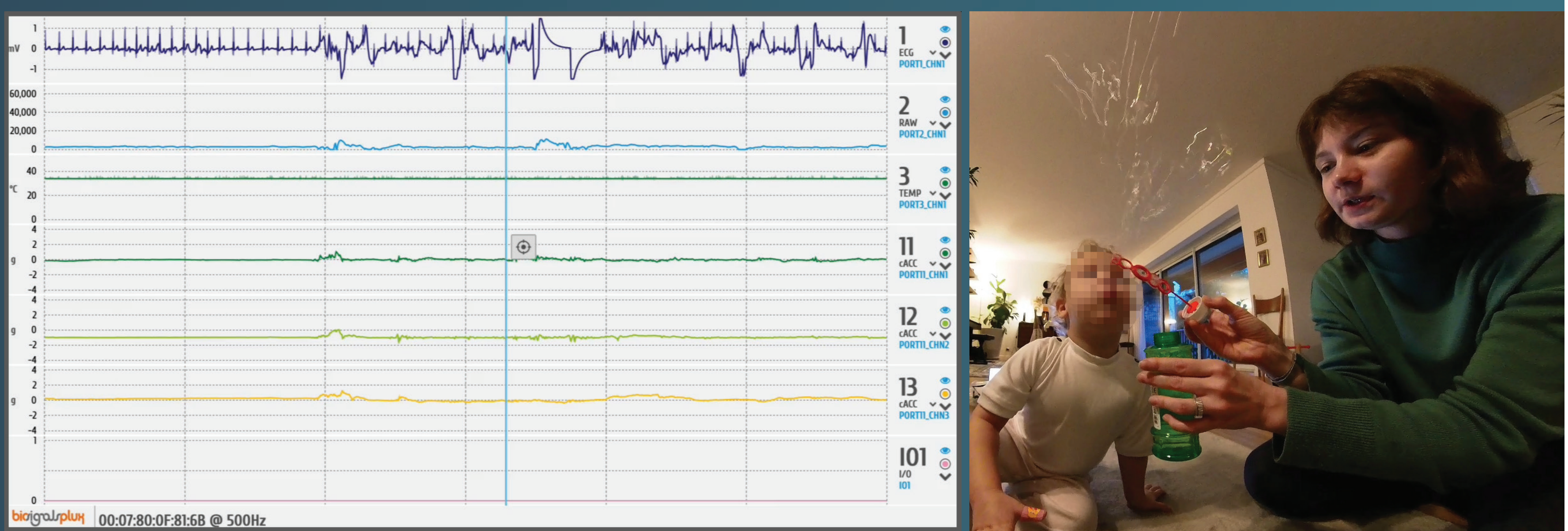


Fig 13: The T-shirt collecting physiological data from a TD child playing with soap bubble in a pilot test about the signal quality.

Fig. 14: Dressing a 2 years ASD child with the sensorised t-shirt, before a pilot test with Panda PlusMe toy.

To ensure the child's maximum comfort and prevent possible allergic reactions, the Sensorised t-shirt is composed of 95% of biological cotton and 5% of elastane. Moreover bio compatible dry electrodes (i.e. electrodes not requiring a gel to function) have been used, so that the child perceives the garment as a normal t-shirt (Fig. 14). Given the adopted materials, and the electronic inner assembly, the electronic wires are waterproof and the T-Shirt is washable under specific conditions, after the removal of the electronic module placed in its back and the coverage of the electronic part with a specific silicon cap.

Preliminary tests show that the T-shirt is well tolerated by most of ASD children (10 participants out of 12: 84%), who have worn it showing no discomfort during the play activities (Fig. 14 and 15).

Fig. 15: Selected clips showing how the t-shirt is well-tolerated by most ASD children.

See video about the sensorised T-shirt: im-twin.eu video/#sensorised_tshirt

High quality physiological signals for machine learning

The pilot tests about the signal quality showed how the sensorised t-shirt, once worn with the right tightness (to ensure the correct contact between skin and sensors), is able to collect good quality data (percentage of usable signal estimated between 85% and 95%) in children engaged in playing activities with the therapist.
The initial analysis indicates that the t-shirt data can potentially be used to train an AI system – e.g. through machine learning techniques – to map the physiological signals into affective states, using a valence/arousal model (i.e. a representation which maps emotions to a 2D space, Fig. 16).

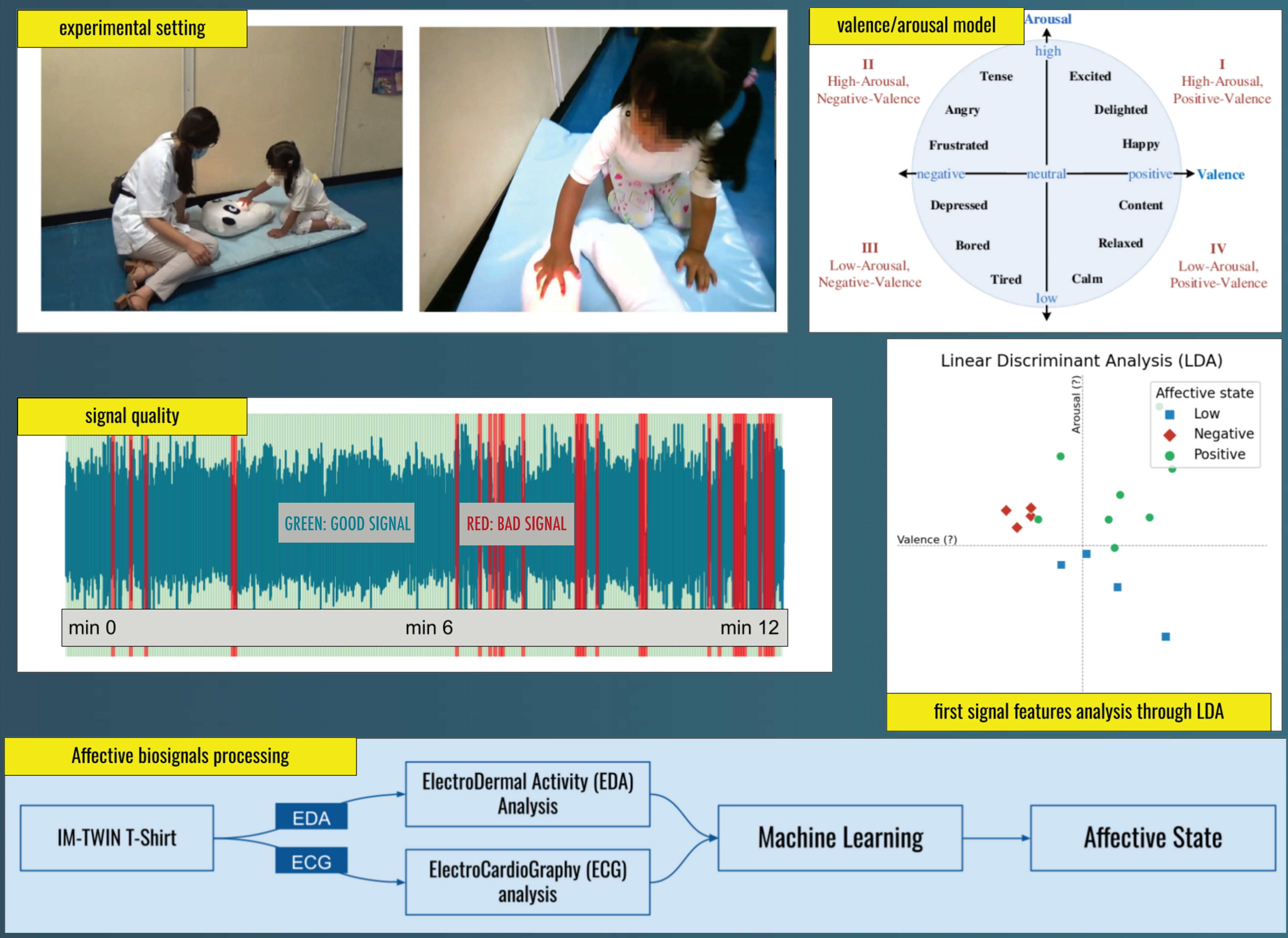


Fig. 16: a 12 minute long test, where an ASD child is involved in a play activity with the therapist and PlusMe. The initial analysis shows how the t-shirt signal is usable (about 90% of data features a good quality), and can potentially be used to categorise the child's effective states (low, negative, positive engagement state) through machine learning algorithms.

See the t-shirt user's manual:
im-twin.eu/wp-content/uploads/2023/05/T-SHIRT_IM_TWIN_UserManual_Version_02.pdf

fCWT: a novel algorithm for fast and accurate processing of electrophisiological signals

Electrophysiological signals (e.g. ECG, EDA, EEG) are intrinsically noisy. The analysis of these data, originating from complex and dynamic systems such as the cardiovascular, respiratory, and integumentary systems, poses a challenge due to their inherent chaotic nature. Furthermore, they are easily distorted due to their low power levels.

In order to process the T-Shirt signals through machine learning algorithms, and obtain information about the subject's affective states, it is crucial to separate meaningful patterns from background noise. Within IM-TWIN project, the researchers developed a novel, outperforming algorithm which allows to analyse these data and use them in real-time application (Fig. 17).

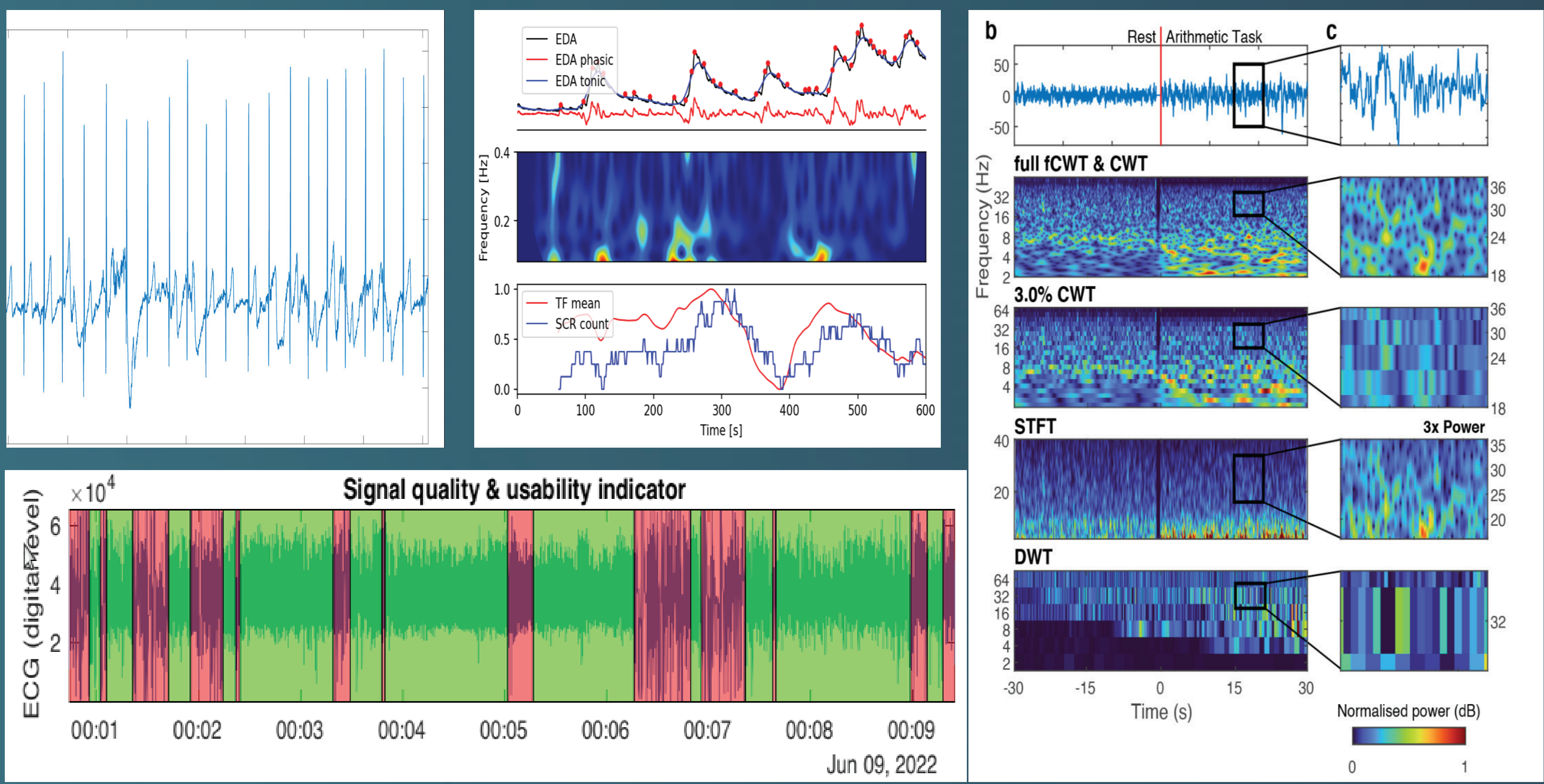


Fig. 17: the EDA and ECG signals collected by the t-shirt are pre processed through the fCWT, a novel fast and accurate time frequency method, developed in the project, to reliable cope with the noise which characterises the physiological data.

See the paper and the open source code (interfaces for Python, Matlab, C++) of the "fast Continuous Wavelet Transform (fCWT)" algorithm: github.com/fastlib/fCWT

3) Eye Contact Detector System

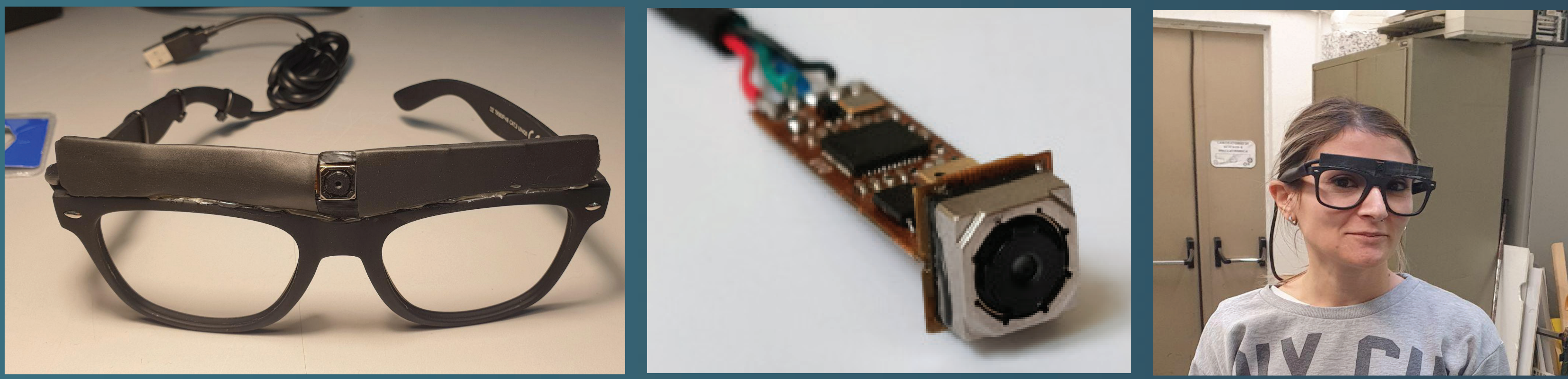


Fig. 18: The 'Camera Glasses' have an embedded micro camera and can be easily worn by the therapist during the activities with children.

The 'Eye Contact Detector System' is a tool developed to detect the eye-contact between child and therapist during the play activities. The video data for the tool are provided by a pair of camera glasses worn by the therapist, i.e. glasses with an embedded micro camera module hidden in the frame, so that the child's attention is not captured by the device (Fig. 18).

After the experimental session, the video data is processed using a recent algorithm [1] based on deep learning, this is, a technique used in Artificial Intelligence (in particular a machine learning), to reliably detects the number and duration of the child-therapist eye contact (Fig. 19 and 20). The evaluation of eye contact is extremely valuable in monitoring ASD children since it is a relevant index of social engagement.

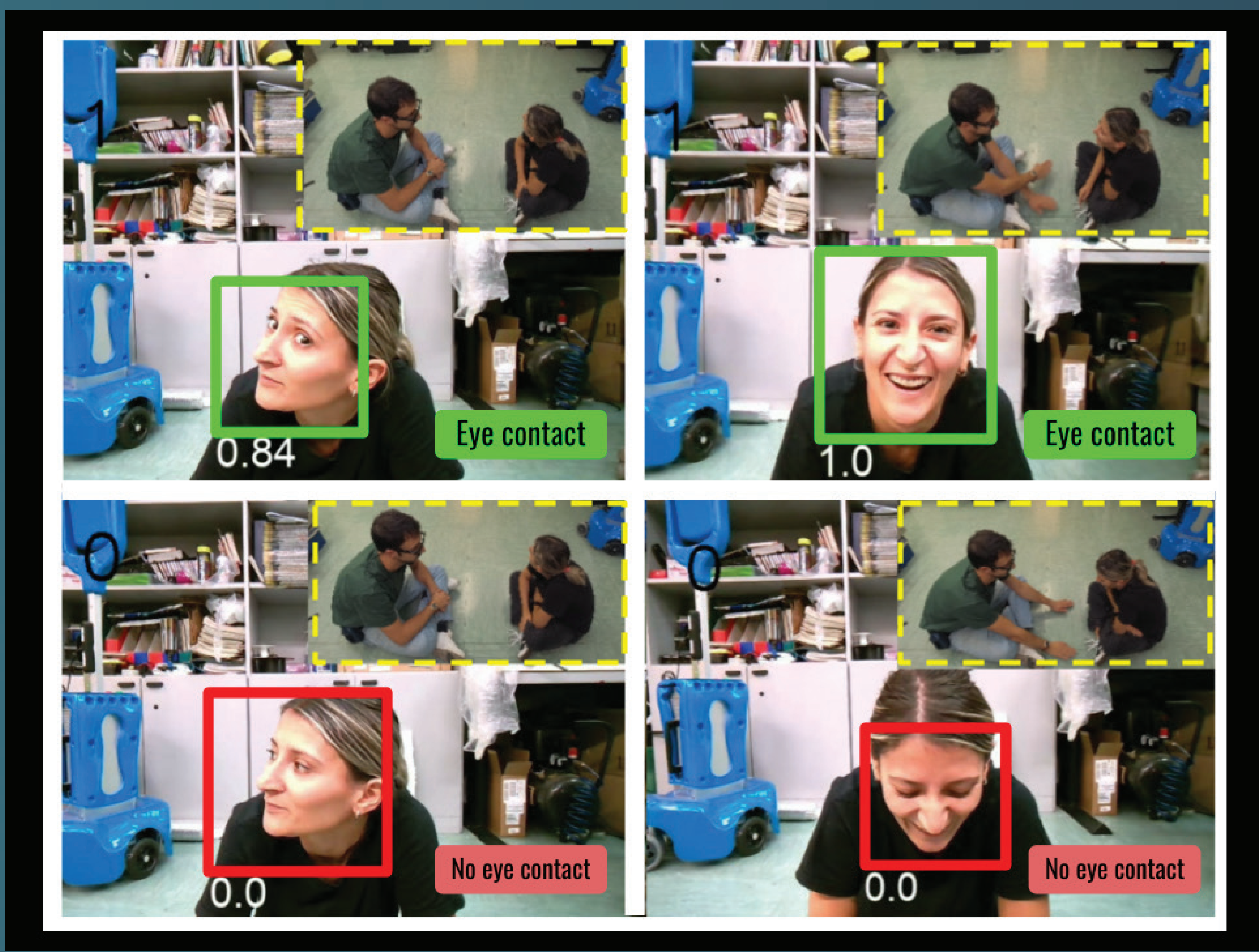


Fig. 19: A reliability test run between two researchers shows how the tool manages to detect the eye contact with a good precision.

[1] Chong, E., Clark-Whitney, E., Southerland, A. et al. Detection of eye contact with deep neural networks is as accurate as human experts. Nat Commun 11, 6386 (2020). https://doi.org/10.1038/s41467-020-19712-x

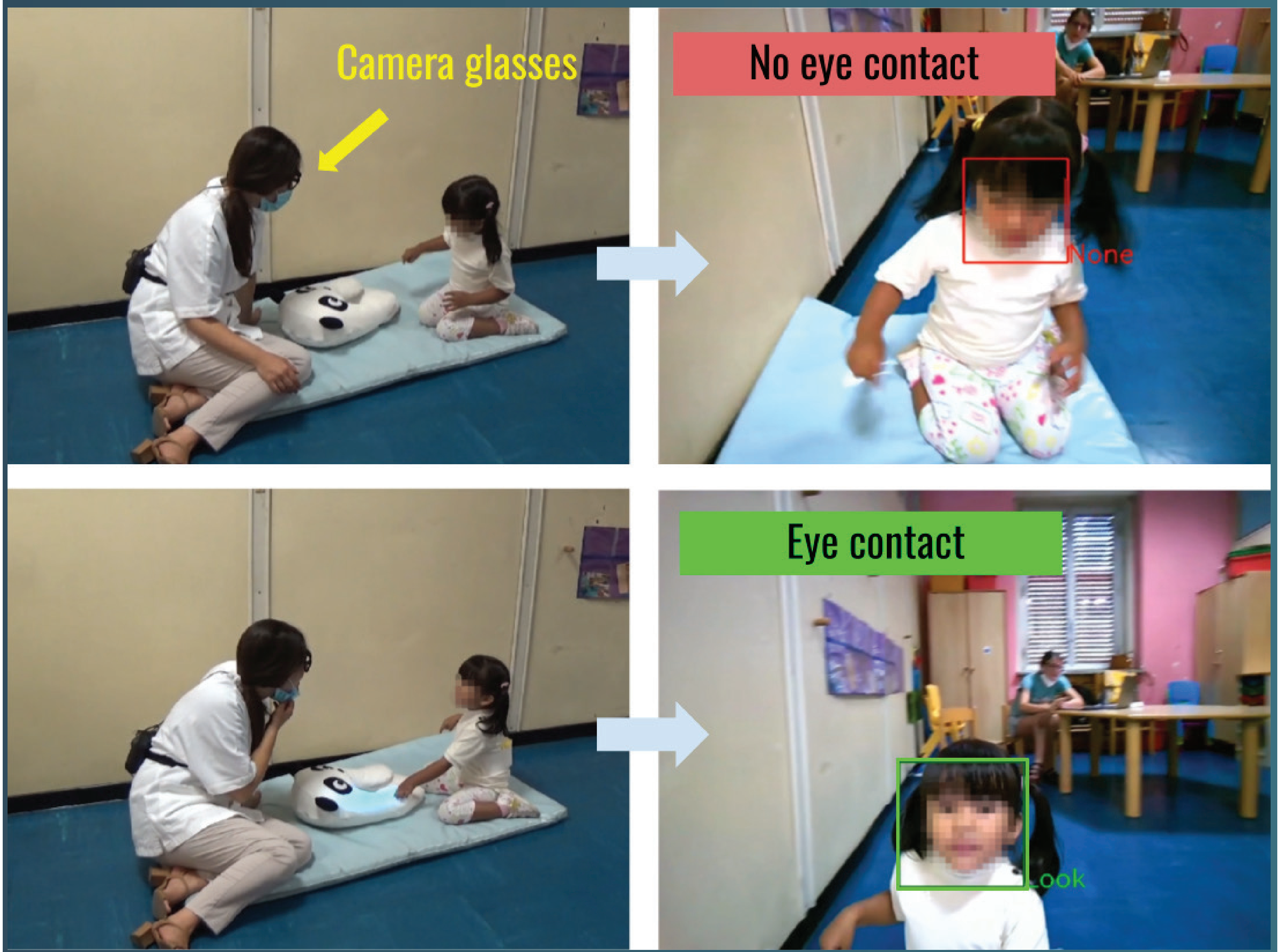


Fig. 20: A therapist, wearing the Camera Glasses to detect eye contacts, while playing with an ASD child and PlusMe interactive toy.

The ‘Eye contact detector’ is currently used in pilot tests with ASD participants (fig 20). During these experiments, the therapist uses the camera glasses, while the child plays with the TWC Panda PlusMe and wears the sensorised T-Shirt.

See the camera glasses demo: im-twin.eu/video/#eye_contact_detector

IM-TWIN system

The 3 components described in the previous sections are now completing a first testing phase. The pilot tests showed how the data collected by the devices are reliable and characterised by good quality. In the next experimental phase, the components will be integrated in a single tool, called the "IM-TWIN system". This novel platform can potentially process the incoming data from the different sources and provide, through machine learning techniques, an objective evaluation of the child's affective state and social engagement during the play activities with the therapist.

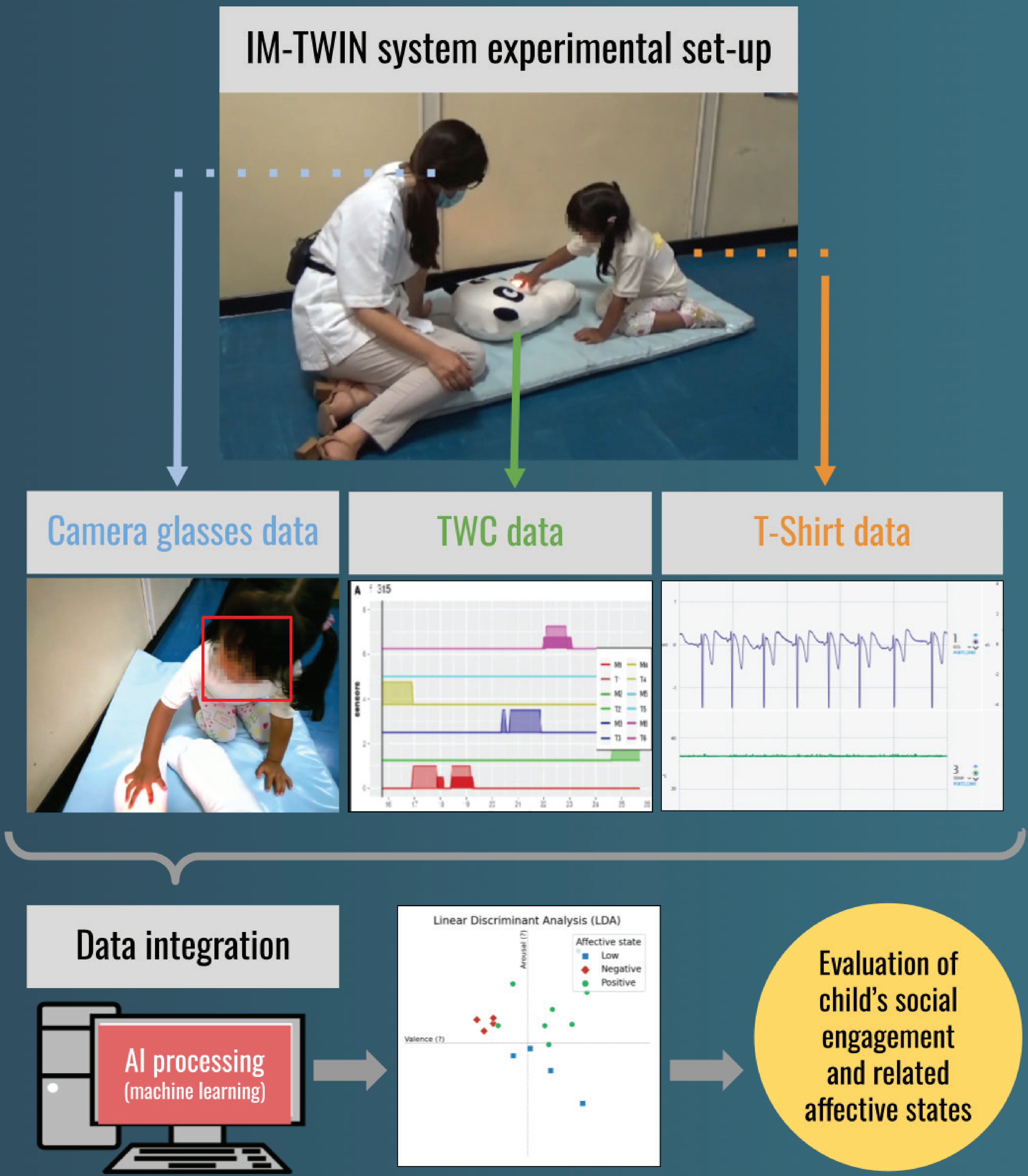


Fig 21: an overview of the whole IM-TWIN system. The various components are going to be integrated to provide the researchers with a general, objective evaluation of the child's affective state and social engagement during the play activities with the therapist.

CONSORTIUM COMPOSITION AND AREAS OF EXPERTISES

4 RESEARCH INSTITUTES

National Research Council of Italy, Institute of Cognitive Sciences and Technologies www.istc.cnr.it	AI, Machine Learning, Neural Networks, Autonomous Robotics, Transitional Wearable Companions
Utrecht University, Department of Information and Computing Sciences www.uu.nl	Affective Computing, Signal Processing, Machine Learning
Learning Planet Institute www.learningplanetinstitute.org	Developmental Psychology, Testing of Typically Developed Children, Testing of Smart Toys
University of Rome Sapienza, Department of Human Neuroscience www.uniroma1.it	Neuro Developmental Psychiatry, ASD diagnosis, Treatment, Research, Large Screening

1 HI-TECH COMPANY

Wearable sensors for the detection of physiological signals: multi-sensor acquisition platforms for biomedical research, biosignals sensor processing	Plux Wireless Biosignals S.A. www.plux.info

1 THIRD PARTY

CNR-ISTC Third Party Quamtum Leap www.quantumleap-ip.com	Technology Transfer, Market Identification, Business Planning

FURTHER MATERIALS AND INFORMATION

Deliverables:

www.https://im-twin.eu/deliverables/

Fideo material:

https://im-twin.eu/video/

Scientific pubblications:

https://im-twin.eu/publications/

Software and manuals:

https://im-twin.eu/hardware-and-software/

The inner electronic of PlusMe toy has been developed in collaboration with the Institute of Microelectronic and Microsystems, National Research Council of Italy, IMM-CNR:

www.artov.imm.cnr.it/

and the engineering company ATon srl:

http://www.aton-srl.it

The Panda *PlusMe* and Octopus *X*-8, designed by Beste Ozcan:

www.beste-ozcan.com

have been realised by the company Soft Doodles:

www.softdoodles.com/

CONTACTS

Dr. Gianluca Baldassarre (coordinator of the project at CNR-ISTC)
gianluca.baldassarre@istc.cnr.it

Prof. Vincenzo Guidetti, MD (University of Rome Sapienza)
vincenzo.guidetti@uniroma1.it

Prof. Dr. Dr. Egon L. van den Broek (Utrecht University)
vandenbroek@acm.org

Prof. Dr. Hugo Gamboa (President of Plux)
hgamboa@plux.info

Dr. Kevin O'Regan (Center for Research and Interdisciplinarity)
jkevin.oregan@gmail.com

"IM-TWIN: from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder" project has recieved funding from the European Union's Horizon 2020 research and innovation programme under grant agreement 952095.

@im-twinproject

im-twin.eu