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IM-TWIN: from Intrinsic Motivations to Transitional Wearable INtelligent companions for autism spectrum disorder

a European funded project

PlusMe AI-augmented behaviour and IM-TWIN 2

Deliverable 3.4

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Acronyms of partners

CNR-ISTC	Consiglio Nazionale delle Ricerche, Istituto di Scienze e Tecnologie della Cognizione (Italy)
UU	Universiteit Utrecht (The Netherlands)
CRI	Centre de Recherches Interdisciplinaires (France)
LA SAPIENZA	Università degli Studi di Roma La Sapienza (Italy)
PLUX	Plux - Wireless Biosignals S.A. (Portugal)

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1. Overview of the deliverable

This final deliverable reports an overview of the 3 technological outputs developed within the IM-TWIN project[1]. In detail, the following devices are described:

1. the *Eye Contact Detector* tool;
2. the *Sensorised T-Shirt*;
3. the *Transitional Wearable Companion* - TWC toys.

These components, which proved to be reliable devices in pilot tests with autistic and neurotypical children, form the core of the *IM-TWIN system*, a novel tool potentially useful to support the monitoring and early intervention in Autism Spectrum Disorders - ASD.

The 3 system components proved to be able to provide high quality data, usable – in principle – as input to train an AI based on *deep learning* for the categorisation of the child's affective states and social engagement. In the future, the IM-TWIN system could be used to understand the affective states of ASD subjects in real time, during the therapeutic activities.

As a support for the document, which is formally a *demonstrator*, the video "*Project final technological outcomes*"[2] provides an overview of the tools through several demonstrator clips. Where necessary, links to individual clips[3] are provided. Additionally, the same overview about the various IM-TWIN system components is conveyed in the deliverable D5.4 "*IM-TWIN system booklet 2*"[4].

2. The IM-TWIN system: a *Proof of Concept*

Figure 1 shows the actual implementation of the IM-TWIN system, achieved at the end of year 3; for comparison, the figure also reports the original IM-TWIN system schema, described in the project proposal. As shown, the system is formed by 3 hardware / software components:

[1] The deliverable does not take into consideration the development of AI-based *PlusMe* behaviour; this feature, originally planned in the Task 4.4 "*Pilot tests of PlusMe-AI*", has been set aside in the project amendment AMD-952095-7.
[2] The video is available at the project website https://im-twin.eu/video/#project_final_technological_outcomes
[3] All video material is available at the project website https://im-twin.eu/video/
[4] The booklet is available as a deliverable at the link https://im-twin.eu/deliverables/ , and as a printable pdf in the "*Promotional Material*" project page, at the link https://im-twin.eu/press-kit/

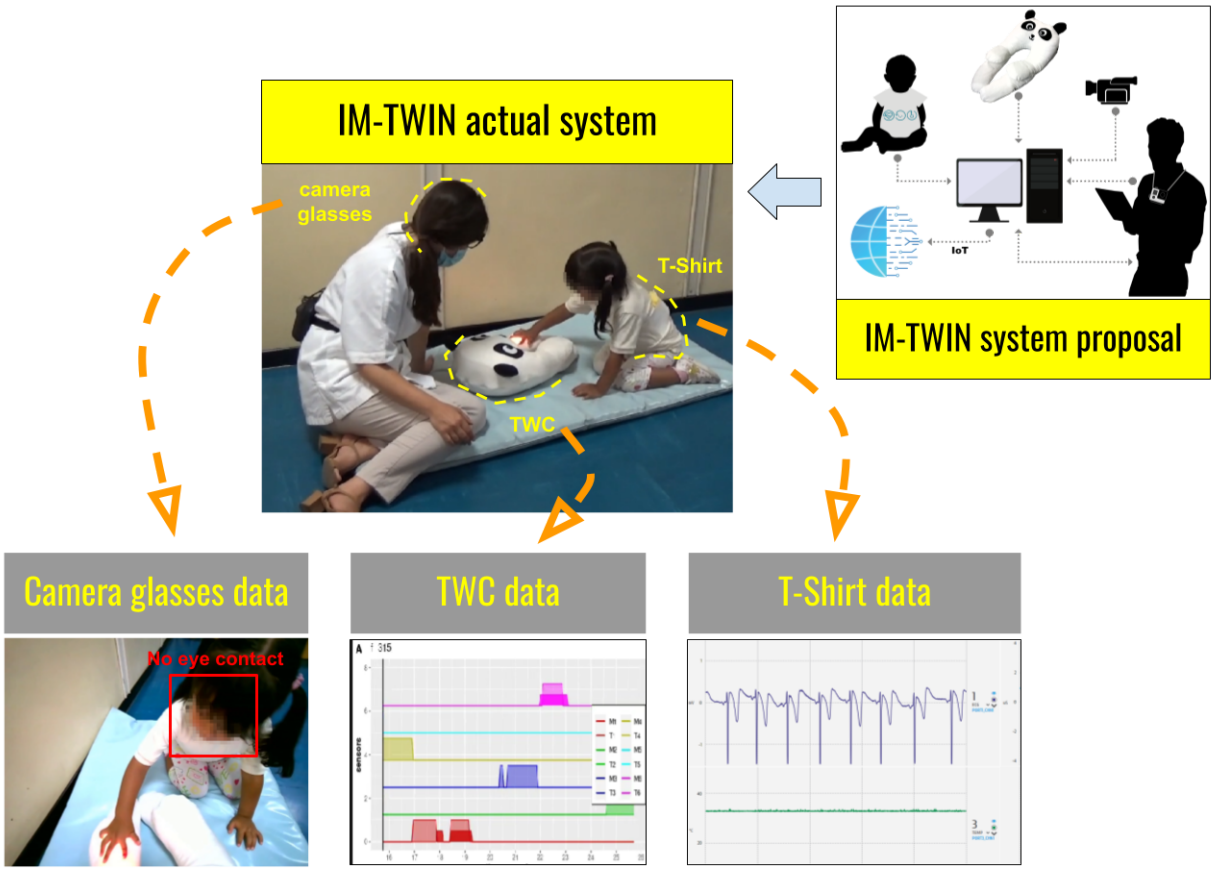

***Figure 1**: Actual implementation of the IM-TWIN system. The 3 components (i.e. the Eye Contact detector; the TWC toy; the sensorised t-shirt), have been tested both individually and partially in integrated fashion. As confirmed in the several pilot tests, the 3 tools provide high quality data, potentially usable for machine learning tasks.*

1) *Eye Contact Detector*: this tool consists of a pair of sensorised glasses for the therapist, embedding an invisible micro camera, and a software for the detection of eye contact. As shown in figure 2, the *Eye Contact Detector* provides a reliable estimation[5] of the eye contact between child and caregiver.

The component is described in detail in the deliverable D2.2 "*Processing of physiological signals, visual info and PlusMe interaction, second version*", section 3 "*Processing of visual information*". A video showing the tool in operation is also available at the link https://im-twin.eu/video/#eye_contact_detector.

[5] The *Inter Rater Reliability* test confirms a very good agreement (k>0.8) between the scorings of the videos provided by the human rater and by the AI.

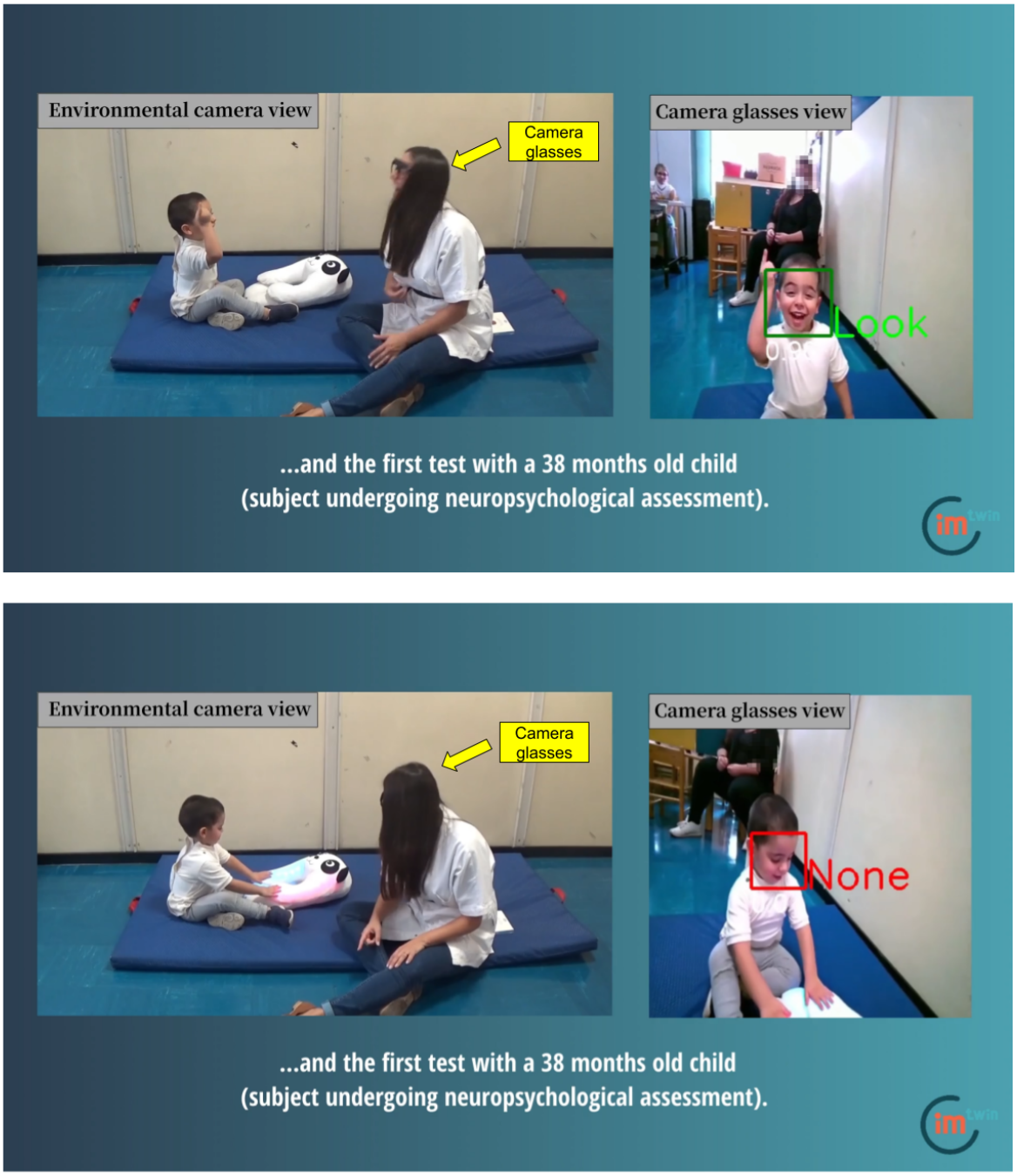

***Figure 2**: Two frames extracted from the project demo video available at the link https://im-twin.eu/video/#project_final_technological_outcomes . The images show a pilot test where the Eye Contact Detector tool was tested with a 38 months old child undergoing neuropsychological assessment.*

2) *Sensorised T-Shirt*: this tool consists of a sensorised T-shirt for the collection of physiological data (ECG, EDA, temperature and body movements) in ASD children.

The T-shirt is described in detail in the deliverable D1.3 *"Physiological Wearable Sensors"* and a "user manual"[6] was provided. A video showing the tool in operation is also available at the link https://im-twin.eu/video/#sensorised_tshirt.

To pre-process the electrophysiological signals, in order to extract meaningful patterns from background noise, and prepare the data as input for deep learning tasks, the algorithm "*fast Continuous Wavelet Transformation - fCWT"* was developed. The fCWT algorithm, provided in the GitHub repository fastlib/fCWT, is described in detail in the deliverables *D2.1 "Processing of physiological signals, visual info and PlusMe interaction, first version"*, section 2.3 "*Processing non-stationary signals and open source repository*".

Since the t-shirt development and test with human participants was a particularly challenging task, figures 3 and 4 show how the t-shirt, if properly worn, can collect reliable data (between 98% and 84% of collected data features high quality) when used with ASD children involved in play activities. In this regard, the initial analyses about the "goodness" of data, for reliable use in machine learning tasks, are described in the deliverables D2.2 "*Processing of physiological signals, visual info and PlusMe interaction, second version"*, section 2 "Processing of physiological signals", and D3.2 "Personalised affect classification and feedback".

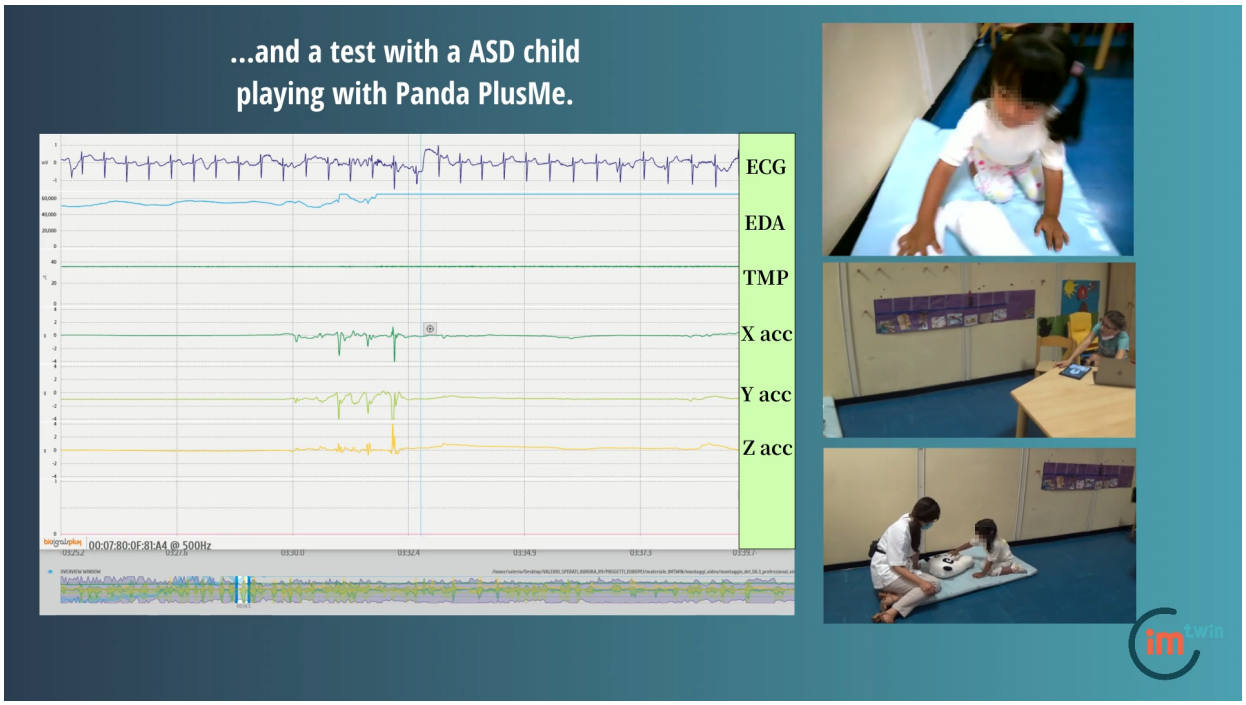

***Figure 3**: a frame extracted from the project demo video available at the link https://im-twin.eu/video/#project_final_technological_outcomes , showing the sensorised t-shirt in a test with a ASD child. In this 12 minutes long test, around 94% of data was characterised by high quality.*

[6] The T-Shirt user manual is freely available at the webpage https://im-twin.eu/hardware-and-software/ .

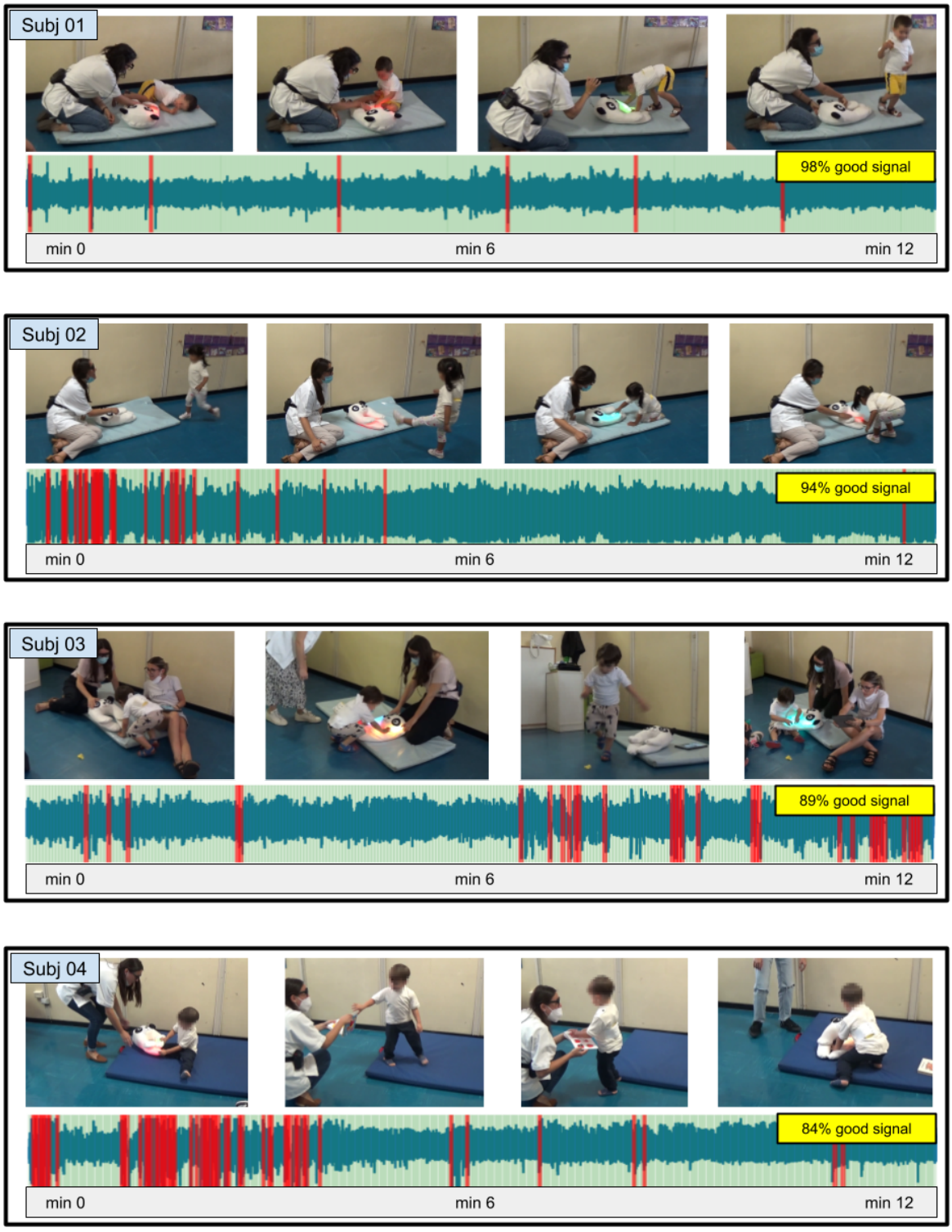

***Figure 4**: Four children with Neurodevelopmental Disorders (top row, Pervasive Developmental Disorders, all other rows Autism Spectrum Disorders), involved in play activities lasting around 12 minutes. For each participant, the visualisation of the t-shirt signal quality (where colour green indicates 'good signal', and red 'bad signal') shows how the collected data features an extremely high quality, between 98% and 84%, potentially usable as input for machine learning tasks.*

3) ***Transitional Wearable Companion*** **- TWC toys**: these interactive toys have been developed as a support tool for therapists, to set up sensory motor play activities to stimulate the social engagement of ASD children. Two prototypes have been developed: *Panda Plusme* and *Octopus X-8*. Videos showing the tools features and data collection capabilities are available at the links https://im-twin.eu/video/#x8_functional_features and https://im-twin.eu/video/#Plusme.

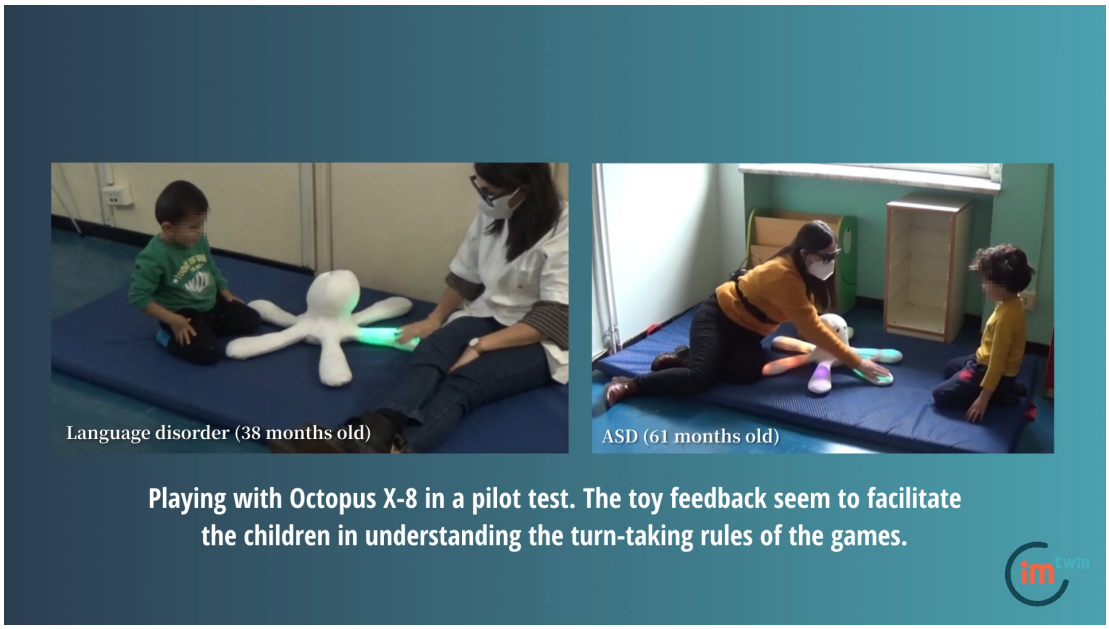

Figure 5*: two frames extracted from the project demo video available at the link https://im-twin.eu/video/#project_final_technological_outcomes, showing the usage of Transitional Wearable Companion Toys with children with ASD and other Neurodevelopmental Disorders.*

3. Future Development

The 3 components described in the previous section have been tested individually and together in some pilot tests. To date, we are continuing to improve the software which allows the TWC and the *Eye Contact Detector*, to collect data in a synchronised way, as described in the deliverable D2.2 "*Processing of physiological signals, visual info, and PlusMe interaction, second version*", section 4 "*Processing of interaction between child PlusMe and therapist*".

In the tests run, the components do not exchanged data in real time[7]. Data processing was indeed mainly carried out at the end of the experimental session for a deeper statistical and AI analysis. In any case, this feature (i.e. the real time data exchange between devices), was described through a demo in the deliverable D3.3 "PlusMe augmented behaviour and IM-TWIN 1" and can still be enabled as needed.

To conclude, the 3 components proved to be reliable tools, able to collect good quality data, potentially usable as input for AI systems based on machine learning techniques for the categorisation of the children' affective states and social engagement (fig. 6).

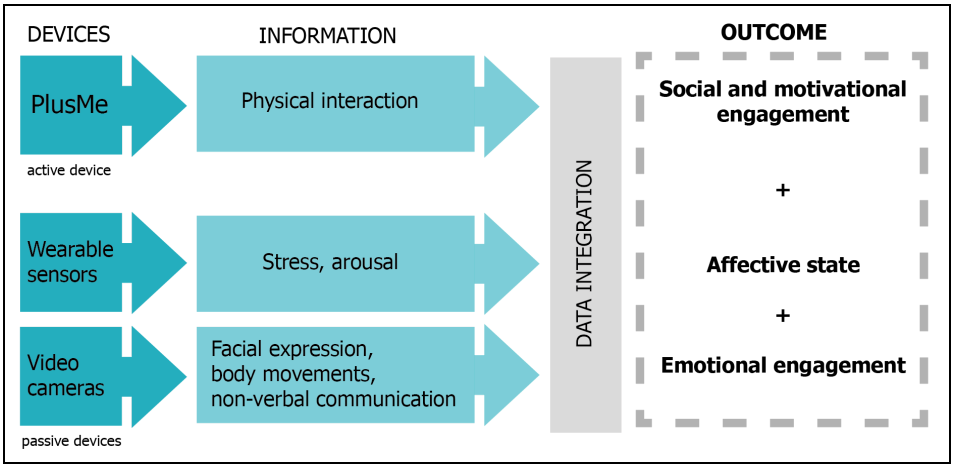

***Figure 6**: the original schema, presented in the project proposal, which shows how the different sources of information (the devices) could be used to detect the general child's level of social engagement and affective/emotional state. The 3 components described in this deliverable proved to be reliable tools for this challenging task.*

[7] This feature is still available and can be enabled to the need.