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1. EXECUTIVE SUMMARY

1.1 Publishable summary

This document proposes an Experience Readiness Level (ERL) framework as a complementary practice to other, pre-existing, Readiness Levels frameworks. ERL is informed by the following six pre-complementary readiness level approaches: Technology readiness level (TRL), Manufacturing (or production) readiness level (MRL), Market readiness level (MARL), Integration readiness level (IRL), System readiness level (SRL), and Cyber security readiness level (CSRL), each of which can in one way, or another be connected to IoT technology development.

Whilst it is certainly true that much of the qualitative evaluation of the maturity of IoT technologies and applications can be described by these pre-existing readiness levels, ERL seeks to address a gap in this assessment landscape. Within the IoT ecosystems it is increasingly common to incorporate new technologies such as autonomous systems, artificial intelligence (AI), voice assistants (VA), virtual reality (VR), augmented reality (AR), wearables, which enhance the user experience and, therefore, have a crucial role in assessing the maturity of new IoT technologies.

Alongside the presentation of ERL as an evaluation concept, this proposal also suggests the use of an Art-led methodology which provides a practical and rich roadmap for deployment. Engagement with Art is fundamentally experiential. For example, imagery, sculpture and movies can generate complex visual stimulation in the observer, prompting multiple reactions from visceral emotion to intellectual understanding. Framing an interaction with a new IoT system as an experience with art adds value to scoping and testing exercises by engaging the user in an experimental and playful mode. It can have the additional virtue of disengaging the experience from the intention of the service or system developer, revealing measurable impacts of usability and engagement outside the scope of a more systems-based assessment.

How you react to Artworks and the experience you have with Art has historically been in the domain of the Art community. Now we want to see how these can be combined as well in the IoT world, where experience is a part of a service. Also, people in the future will pay for experience as a service. We have aimed to find a common ground of inputs and interests through the ERL policy.

1.2 Non-publishable information

This document is public.

2. Introduction

2.1 Purpose and target group

The Experience Readiness Level (ERL) is a new notation that measures the capability of IoT systems to trigger a well-suited user experience [1][3]. By adopting and implementing the ERL, the EU will fulfil its goals of making a Digital Single Market (DSM) that puts humans (i.e. European citizens) at the centre [2]. A shift of attention from production to involving existing and new communities at an early stage of the IoT development is fostered and advocated. For the adoption of IoT by masses in full confidence, it is important stop thinking about IoT as simple objects and start thinking of IoT as triggers for better lives [1].

The ERL framework is a complementary practice to other, pre-existing, readiness levels frameworks and is proposed for analysing and evaluating next generation IoT technologies and applications by combining with a body of methods arising from the arts. The framework and its associated levels can be applied in the specific areas of innovation of the IoT European Large-Scale Pilots Programme: food and farming, healthy aging, public mass events, self-driven vehicles and smart cities. Furthermore, the framework aims to promote the cross-fertilisation between those domains as well as to nurture innovative, business-driven technical applications that might emerge from specific combinations of those fields.

The individual levels considered in the report result from the wide experience of the partners of CREATE-IoT committed to develop and implement the ERL. The framework is aimed to foster the take up of IoT in Europe, and to enable the emergence of IoT ecosystems supported by open innovation, technologies and platforms.

The target groups are the IoT technology and application developers, business developers, and industrial stakeholders within the different industry sectors and application domains, and artist community involved in stimulating innovation, creativity and adoption within the IoT ecosystems via the integration of IoT and Art.

2.2 Contributions of partners

ARTS: Contribution to an event addressing experience and the integration with art. Links with STARTS – the Science, Technology and the Arts initiative of the Digital Single Market.

SINTEF: Defined the Experience Readiness Level (ERL) concept and the links with IoT research and development. Contributed to the methodology of defining ERL. Described the readiness level frameworks used in measuring complex systems and contributed on the pre-complementary readiness level approaches. Contribution on experience readiness level and the integration with art.

FE: Contribution on the integration of Art and ICT as a catalyst and framework and TRL and ERL measures using co-creation methodologies such as Open Prototyping.

2.3 Relations to other activities in the project

The activities are related to the work on common methodology and KPIs for design, testing and validation presented in delivery D01.04 and the methodology for the integration of art and ICT defined in D03.01.

3. PRE-COMPLIMENTARY READINESS LEVEL APPROACHES

The Experience Readiness Level (ERL) is a complimentary approach to several different readiness levels defined. Some of these readiness level methods are introduced in the subsections below. This is not an exhaustive list but gives an overview of several different and relevant readiness levels.

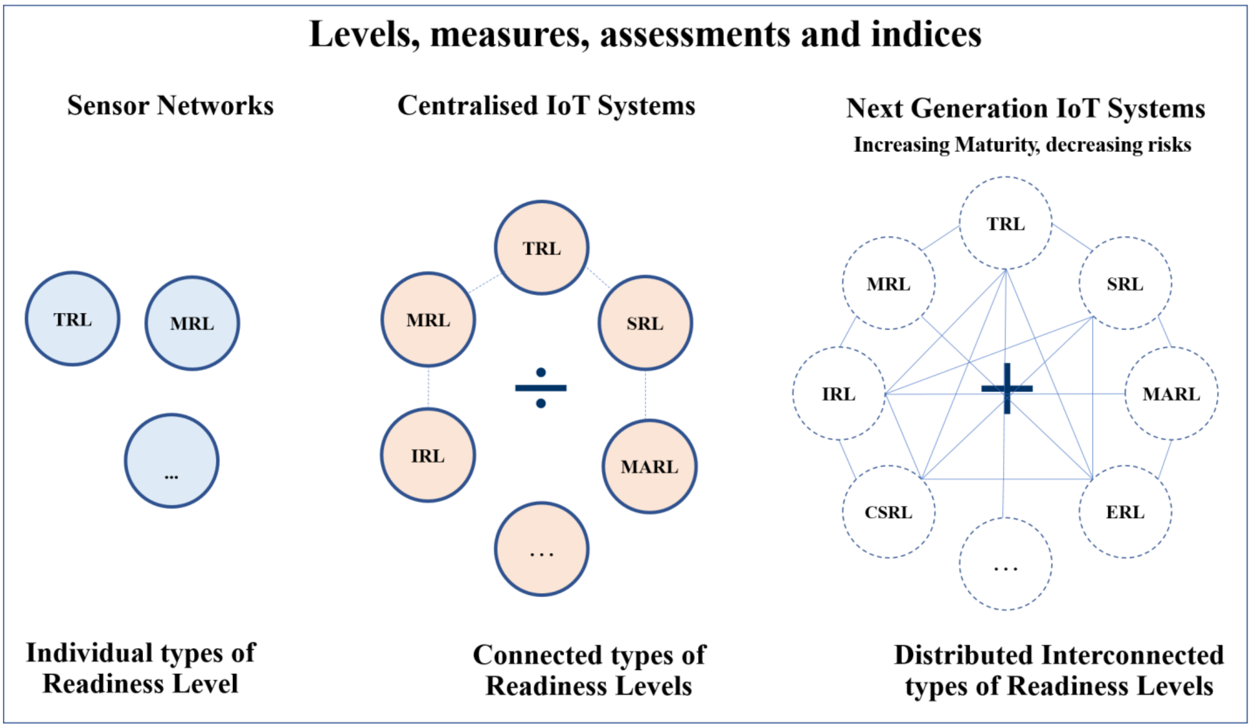

Figure 1: The evolution of readiness levels

Figure 1 illustrates the evolution of the use of different readiness levels (technology, manufacturing, integration, system, etc.) and the application of distributed interconnected readiness levels to next generation IoT systems. This document presents the first attempt to create an ERL description and assessment that maps precisely to an ERL framework for IoT systems/applications that can be used together with other readiness level frameworks to support the advancement in the development of next generation IoT systems and the adoption of the advancements in IoT, VR/AR, AI, Autonomous vehicles, Internet of Robotic Things (IoRT) technology development.

3.1 Technology readiness level (TRL)

Technology Readiness Level (TRL) is a well-known tool used to describe the maturity of a technology. The scale ranges from level 1 to level 9, where each level characterises the technology development progress, from original idea to product. [1]:

- **TRL 1** - Basic principles observed.
- **TRL 2** - Technology concept formulated.
- **TRL 3** - Experimental proof of concept.
- **TRL 4** - Technology validated in lab.
- **TRL 5** - Technology validated in relevant environment (industrially relevant environment in the case of key enabling technologies).
- **TRL 6** - Technology demonstrated in relevant environment, (industrially relevant environment in the case of key enabling technologies).

- **TRL 7** - System Prototype demonstration in operational environment.
- **TRL 8** - System complete and qualified.
- **TRL 9** - Actual system proven in operational environment, (competitive manufacturing in the case of key enabling technologies; or in space).

3.2 Manufacturing readiness level (MRL)

According to the best practice document "Manufacturing Readiness Level (MRL) Deskbook" (prepared by the DSD manufacturing technology program in collaboration with the Joint Service/Industry MRL Working Group), ten Manufacturing (or production) Readiness Levels (PRLs) are defined [7]:

- **MRL 1 -** Basic manufacturing implications identified, (focus is to address production shortfalls and opportunities needed to achieve the given objectives).
- **MRL 2 -** Manufacturing concepts identified, (characterized by describing the application of new manufacturing concepts. Typically including identification, paper studies and analysis of material and process approaches, and understanding of manufacturing feasibility and risk is emerging).
- **MRL 3** - Manufacturing Proof-of-Concept (PoC) developed, (starts the validation of the manufacturing concepts through analytical or laboratory experiments. Materials and processes have been characterized for manufacturability and availability, but further evaluation and demonstration is required. Experimental HW/SW models have been developed in a laboratory environment that may possess limited functionality).
- **MRL 4** - Capability to produce the technology in a laboratory environment, (act as an exit criterion for the phase of material solution analysis. The technologies should have matured to a level (at least TRL 4) that indicates that the technologies are ready for the technology maturation and risk reduction phase of acquisition. Required investments have been identified; processes to ensure manufacturability, producibility, and quality are in place and are enough to produce technology demonstrators; manufacturing risks have been identified for building prototypes and mitigation plans are in place; target cost objectives have been established and manufacturing cost drivers have been identified; producibility assessments of design concepts have been completed; and key design performance parameters have been identified together with special tooling, facilities, material handling and skills required).
- **MRL 5 -** Capability to produce prototype components in a production relevant environment, (the technologies should have matured to at least TRL 5; the industrial base has been assessed to identify potential manufacturing sources; a manufacturing strategy has been refined and integrated with the risk management plan; identification of enabling/critical technologies/components is complete; manufacturing processes/procedures are still in development, but prototype materials, tooling and test equipment, together with personnel skills have been demonstrated on components in a production relevant environment; manufacturing technology development efforts have been initiated or are ongoing together with producibility assessments of key technologies/components; and a cost model has been constructed to assess projected manufacturing cost).
- **MRL 6** - Capability to produce a prototype system or subsystem in a production relevant environment, (the technologies should have matured to at least TRL 6 and normally denotes acceptance of a preliminary system design; the majority of manufacturing processes have been defined/characterized; preliminary design has been completed; producibility assessments and trade studies of key technologies/components are complete; prototype manufacturing processes and technologies, materials, tooling and test equipment, together with personnel skills have been demonstrated on systems and subsystems in a production relevant environment; cost, yield and rate analyses have been performed to assess how prototype data compare to target objectives; appropriate risk reduction program to achieve cost requirements or establish a new baseline in place; producibility

considerations have shaped system development plans; and long-lead and key supply chain elements have been identified).

- **MRL 7** - Capability to produce systems, subsystems or components in a production representative environment, (the technologies should be on a path to achieve TRL 7; detailed system design activities are near completion; material specifications have been approved and materials are available to meet the planned pilot line schedule; manufacturing processes/ procedures have been demonstrated in a production representative environment; detailed producibility trade studies are completed and enhancements/risk assessments are underway; cost model updated with detailed designs, rolled up to system level, and tracked against allocated targets; unit cost reduction efforts prioritized and underway; yield/rate analyses updated with production representative data; supply chain and supplier quality assurance assessed and long-lead procurement plans in place; manufacturing plans and quality targets developed; and production tooling and test equipment design/development initiated).
- **MRL 8** - Pilot line capability demonstrated, (the technologies should have matured to at least TRL 7 or 8; detailed system design completed and sufficiently stable to enter low rate production; all materials, manpower, tooling, test equipment and facilities are proven on pilot line and available to meet the planned low rate production schedule; manufacturing and quality processes/procedures are proven and under control in a pilot line environment ready for low rate production; cost model and yield and rate analyses updated with pilot line results; supplier qualification testing and first article inspection completed; supply chain established to support low rate initial production).
- **MRL 9** - Low rate production demonstrated, (the technologies should have matured to TRL 8 or 9 and is normally associated with readiness for full rate production; all systems engineering/design requirements met such that minimal system changes will arise; major system design features stable and proven in test/valuation; materials, parts, manpower, tooling, test equipment and facilities are available to meet planned rate production schedules; manufacturing process capability in a low rate production environment is at an appropriate quality level to meet design key characteristic tolerances and production risk monitoring ongoing; low rate initial production cost targets met and learning curves analysed with actual data; and cost model developed for full rate production environment and reflects the impact of continuous improvement).
- **MRL 10** - Full Rate Production and lean production practices in place, (the technologies should have matured to TRL 9 and normally associated with the production/ sustainment phases of the acquisition life cycle; engineering/design changes are few and generally limited to quality/cost improvements; system, components or items are in full rate production and meet all engineering, performance, quality and reliability requirements, and the manufacturing process capability is at the appropriate quality level; all materials, tooling, inspection and test equipment, facilities and manpower are in place and have met full rate production requirements; rate production unit costs meet goals, and funding is sufficient for production at required rates; and lean practices are well established and continuous process improvements are ongoing.

3.3 Market readiness level (MARL)

A well conducted marketing plays an important role in the success of innovation related to the development and implementation of IoT as the technologies and applications advances. The development of marketing maturity assessment seems appropriate in analogy to the well-known method of TRL and other readiness level methods. According to the article "Conceptual aspects of marketing readiness level assessment model", six Market Readiness Levels (MARLs) are defined as follows [4]:

- **MARL 1** - The concept of the projected product is studied, explained and improved. (The main task is the adoption of a long-term strategic solution. The concepts of a future products

shall be studied, proposed and rationalized in order to choose the most optimal variant. The concept of innovative products and services shall be approved, and the issue of drawing up the plan of its further development and commercialization raised).

- **MARL 2** - Pre-planning of main features of the product and production volume is completed. (A deeper and more thorough study of key parameters, critical technology elements and features of innovation to comply with the potential consumers'/customers' requirements, and future product architecture measures shall be obtained together with a preliminary assessment of the volume of future sales and potential profit. Innovation developers' first interaction with the consumers/customers as participants (consumer/customer oriented and feedback seeking) to the process of innovation based on the win-win principle).
- **MARL 3** - The first phase of prototype testing is carried out by the consumers/customers. (A prototype design shall be completed, the sample produced, and the design of the future product shall be carefully defined. Technological processes shall be verified, and relationship with the selected design explored. Protype testing by the consumers/customers shall be carried out and resulting in a presentation of improvements/problems and optimal product design).
- **MARL 4** - The second phase of prototype testing by the customers is finished and priority plan for sales market development is made. (Prototype modifications and demonstrations for the consumers/customers in order to verify the running processes on the level of system integration of separate technologies. The main purpose is projected products approval at system level).
- **MARL 5** - Test marketing is completed and readiness to enter the various sales markets is demonstrated. (The technology development and system integration shall be completed. Information about distribution channels, products marketing, special advertising/ promotion aspects, and surrounding environment obtained. Organization of product test marketing in order to clarify if additional activities in order to reduce risks and costs are advisable, have in mind that the innovation maybe not pass national standards or can be rejected by the consumers/customers. How to deal with commercialization challenges shall be organized. Sales department shall be established, and active training of personnel carried out, together with organization of after-sales services, customer service, support service and innovation technical support services. First commercial sales are successful, and first profit is gained).
- **MARL 6** - Distribution and product sale in the open market is organized. (Full-scale distribution channel program established, promotion and product sale in different markets organized. Successful cooperation and collaboration with key customers set, and agreement and approval of obtained commercial rates based on stable positive sales dynamics completed).

3.4 Integration readiness level (IRL)

The integration readiness level (IRL) is a metric that can be used to evaluate the integration readiness of two TRL assessed technologies [5], a tool for systematic measurement of the interfacing of compatible interactions for various technologies and the consistent comparison of the maturity between integration points [6]. While TRL has been used to assess the risk associated with developing technologies, IRL is designed to assess the risk of integration. IRL can be used to describe and improve the integration maturity of a developing technology with another developing and mature technology. The seven IRLs below are based on the article "From TRL to SRL: The Concept of Systems Readiness Levels" [6]:

- **IRL 1** - Interface identification, (the interfaces between the IoT technologies (and other technologies) have been identified with enough detail to allow characterization of the relationships).

- **IRL 2** - Interaction characterization, (there are some levels of specificity to characterize the interactions between IoT technologies (and other technologies) through their interfaces).
- **IRL 3** - Compatibility properties, (there are HW and SW compatibility/interoperability between the IoT technologies (and other technologies) that are suitable for integration and interaction.
- **IRL 4** - Quality and assurance, (there is enough detail in the quality and assurance of the integration between IoT technologies (and other technologies)).
- **IRL 5** - Control routines, (there is enough control between IoT technologies (and other technologies) necessary to establish, manage, and terminate the integration.
- **IRL 6** - Application adaption, (the integrating IoT technologies (and other technologies) can accept, translate, and structure information for its intended applications.
- **IRL 7** - Verification and validation, (the integrations of IoT technologies (and other technologies) have been verified and validated with enough detail to ensure satisfactory functionality.

3.5 System readiness level (SRL)

The system readiness level is metric for the individual TRLs in a system and their subsequent integration points with other technologies (IRL) [6]. According to the article "From TRL to SRL: The Concept of Systems Readiness Levels", the resulting functions of these interactions are correlated to five SRLs, as described below [6]:

- **SRL 1 -** Concept refinement, (the initial concept refined, and a system and technology development strategy developed).
- **SRL 2 -** Technology development, (the technology risks reduced, and an appropriate set of full system integration technologies determined).
- **SRL 3 -** System development and demonstration, (A new or improved system development demonstrated, including for instance reduced integration and manufacturing risks; ensured operational supportability; reduced logistics footprint; implemented human systems integration; designed for producibility; ensured affordability and protection of critical program information; demonstrated system integration, interoperability, safety, and utility).
- **SRL 4 -** Production development, (operational capabilities that satisfy the application needs are achieved).
- **SRL 5** - Operations and support, (a support program executed; that meets the operational support system performance requirements and ensure that the system sustains in the most effective manor over its total life-cycle).

3.6 Cyber security readiness level (CSRL)

The cyber security readiness level (CSRL) is a metric that can be used to evaluate the security readiness of an IoT system or application.

- **CSRL 1 -** Identification and observation of basic security principles and properties. Baseline security and applies to the normal security measures in IoT architectural layers. Areas such as security screening, security awareness are addressed at application level.
- **CSRL 2 -** Definitions of practical security solutions and mechanisms for IoT applications. Formulation of security mechanisms concepts. Different levels of threats are identified, and the possible vulnerable items are identified. Security patch updates for software and hardware are considered.
- **CSRL 3 -** Observation and analysis through security analysis research, laboratory replication or security breach experiments. On the air security updates are considered. At the application level reviews of the security posture and third-party risk assessments are infrequent.

- **CSRL 4 -** IoT security proof of concept solutions and mechanisms that are based upon the aggregation of applications and concepts to demonstrate viability.
- **CSRL 5 -** Validation defined as the refined integration of IoT applications or concepts including security features to confirm validity. The security solutions are limited to proof of concept solutions and limited to specific use cases. Scalability and interoperability of IoT security solutions is not demonstrated. The security solutions cover specific IoT architectural layers.
- **CSRL 6 -** Simulated IoT security demonstration of a near-end state security solution and testing in a simulated environment.
- **CSRL 7 -** Real-world IoT security solutions of a near-end state solution and testing in an appropriate real-world environment and the solutions are used to react to breaches on a case-by-case basis. The IoT security solutions in many cases are provided by third parties.
- **CSRL 8 -** Qualified IoT end-to-end security solution which is the completion of end state solution and refinement through security testing, as part of the proactive measures to perform regularly reviews of the security solutions and regularly IoT applications risk assessments.
- **CSRL 9 -** Proven end-to-end security solutions across the IoT architectural layers implementing security-by-design, security-by-default mechanisms that are based upon final solution implementation and success. This is the level of progressive IoT security that includes setting, managing, and reviewing the security measures continuously using actively security technologies as proactive steps to reduce/eliminate the value of compromised information to hackers.

4. EXPERIENCE READINESS LEVEL CONCEPT

4.1 Experience readiness level (ERL) concept

As mentioned in section 3, the Experience Readiness Level (ERL) is a complementary approach to other readiness level, like Technology Readiness Level (TRL), Production Readiness Level (PRL) and Market Readiness Level (MRL) [1].

ERL measures the capability of IoT systems and applications to trigger a well-suited user experience, a measure that steps away from thinking about IoT as simply object-based, to embrace instead the potential of dynamic exchange between technology and humans with a particular emphasis on the empowerment of the user and a deepening of their experience [1][3].

The preferred roadmap utilises an integration of Art and ICT as a catalyst and framework for the process.

A shift of attention from labs and drawing boards to involving existing and new communities at an early stage of IoT development is fostered and advocated. If the goal is the adoption of IoT by masses in full confidence, it's important we stop thinking about IoT as objects and start thinking of IoT as triggers for better lives. The Experience Readiness Level (ERL) is a new notion that introduces the focus on 'better lives' and moves the attention from the production to the consumption level of IoT. [3, section 4.5.7]

By designing, developing, implementing and adopting ERL we contribute to fulfilling the goal of making a Digital Single Market (DSM) that puts humans at the centre [2]. Additional benefits are accrued through a more effective engagement of external partners, collaborators and other stakeholders [3, section 4.3.3]

ERL is most effectively facilitated through the use of a co-creation framework. This is described as activities where customers, end users, application owners, artists and developers are involved as active participants in the design and development of, for example, personalized IoT applications, use cases, products, services, and experiences in IoT platforms ecosystems [3]. ERL is both tested by and demonstrated through such a co-creation framework.

The design, development, implementation and adoption of experiential elements and platforms are driven by consumer IoT experiences, with an emphasis on the co-creation of experiences through the involvement of all manner of stakeholders, from industry experts to novice consumers.

ERL can be tested at any level of maturity, from fundamental research, to operational deployment. That is to say, user needs, and experience are addressed at each stage in the development of the technology, not only at the end. Incorporating ERL based feedback into the process from initial prototype to operational readiness is core to the generation of a usable, desirable and robust user experience.

The ERL concept can be combined with other readiness level frameworks to define an associated readiness assessment used to identify or assess the precise and practical readiness level status of a complex IoT system and application. This allows the identification of the overall level of readiness or maturity of a given IoT technology/system/application as it relates to the *experience*, its *usability* and its *refinement* to be used by end-users/customers. One that emphasizes situational awareness, usability, emotional connection, amongst other factors.

ERL can also be used as a method to track IoT system development as it pertains to user readiness from an HCI perspective.

Proposed KPIs for use with ERL are summarised in the table below [3, 4.5.7].

Table 1: Proposed KPIs for use with ERL

Name/Identifier	Description	Metric	Method of collection and measurement
Design of experiential elements	Number of co-created concepts and sketches that express basic principles and technologies that will support the IoT experience	Number	Survey, reporting
Experiential platform developed	Number of prototypes and mock-ups developed by artists, scientists and technologists through co-creation	Number	Survey, reporting
Co-creation of experiences with expert consumers	Quality of experience of expert consumers immersed in participative experiences developed through co-creation and demonstrated through operational prototypes, user interfaces, participative experiences	Textual	Behavioural analysis based on audio-visual observation, interviews
Co-creation of experiences with novice consumers	Quality of experience of novice consumers immersed in participative experiences developed through co-creation and demonstrated through operational prototypes, user interfaces, participative experiences	Textual	Behavioural analysis based on audio-visual observation, interviews
Consumer-driven IoT experience	Quality of new applications and experiences co-created through demonstrations in operational environments	Usability Metrics (e.g. completion rate, task time, comprehension)	Users will be asked to explore an experience while thinking-aloud performing tasks and asked questions aimed at probing their understanding of the experience.

4.2 TRL and ERL measures

One barrier to industrial innovation in the IoT is to know which technology capabilities are useful for the development of new products and services. It is also true to say that there are challenges in engaging end-users when developing next generation capabilities.

Due to the complexity and novelty of next generation IoT capabilities, stakeholder awareness and acceptance can be low. For industry transfer the abstraction must be expressed in a way that is meaningful to the stakeholder. The current state of the art remains dependent upon the expertise of specialists to translate and to realise these connections between the high-level abstraction and the lower levels.

Co-creation methodologies such as Open Prototyping, described in D03.01 [2], are suited to fundamental research and development, employing novel engagement and innovation methods, including the combination of Art and ICT, which can be effective at overcoming these hurdles.

If technology maturity is measured by TRL (Technology Readiness Level), and experience maturity by ERL (Experience Readiness Level), then an effective co-creation process would loop between considerations of TRL and ERL, with users and creatives actively involved in the loop. The expression of an IoT system is progressively developed and refined holistically by all stakeholders, and users are empowered to identify the different components on which to apply co-creation.

Creative methods including visualisation, creative prototypes, new media art and participative experiences are applied to devise and evaluate novel approaches to demystify, navigate and engage the abstraction layer. User evaluation then tests how users are able to grasp and influence the abstraction and build trust in the solutions. Living lab methodologies facilitate

demonstrations in real-world settings, and this effective and scaled combination of Art and ICT stimulates innovation and builds user trust and acceptance.

Table 2: Co-creation activities mapped to IoT technology and ERL

TRL/ERL	1-2 Fundamental/ feasibility research	3-5 Technology and experience development	6-8 Technology and experience demonstration	9 Operational deployment
TRL	Basic principles and concepts	From experimental proof of concept to validated in relevant environment	From demonstrated in relevant environment to qualified	Proven in operational environment
ERL	Scenarios, illustrations, objects and narratives communicate principles and concepts.	Experience prototypes, mock-ups to enable testing and trials of early samples.	Operational prototype, user interface, participative experiences.	User experience, service support.
Co-creation Activity	Scenario and concept development	Making and prototyping	Public testing and trials, exhibits, living labs	Communications and service launch

4.3 Trigger experience indicators for IoT systems

The Experience Readiness Level indicators can support the design and redesign process of new IoT technologies and applications, providing input and feedback when it is required. Incorporating ERL indicators in this way also allows for existing experience measures to be captured and incorporated in new developments of these technologies and applications. Such a process may also be of value when considering performance and experience improvements, enabling block upgrades to be committed with a high degree of confidence.

Experience level indicators need to be connected to design studies in order to understand more of the end users' perspective of their experiences. Design research is considered along three directions as presented in [19]:

- Design practice - commercial development or case studies.
- Design studies - looking at design practice and theory development from a distance.
- Design exploration - introducing design as a tool to perform research into other topics.

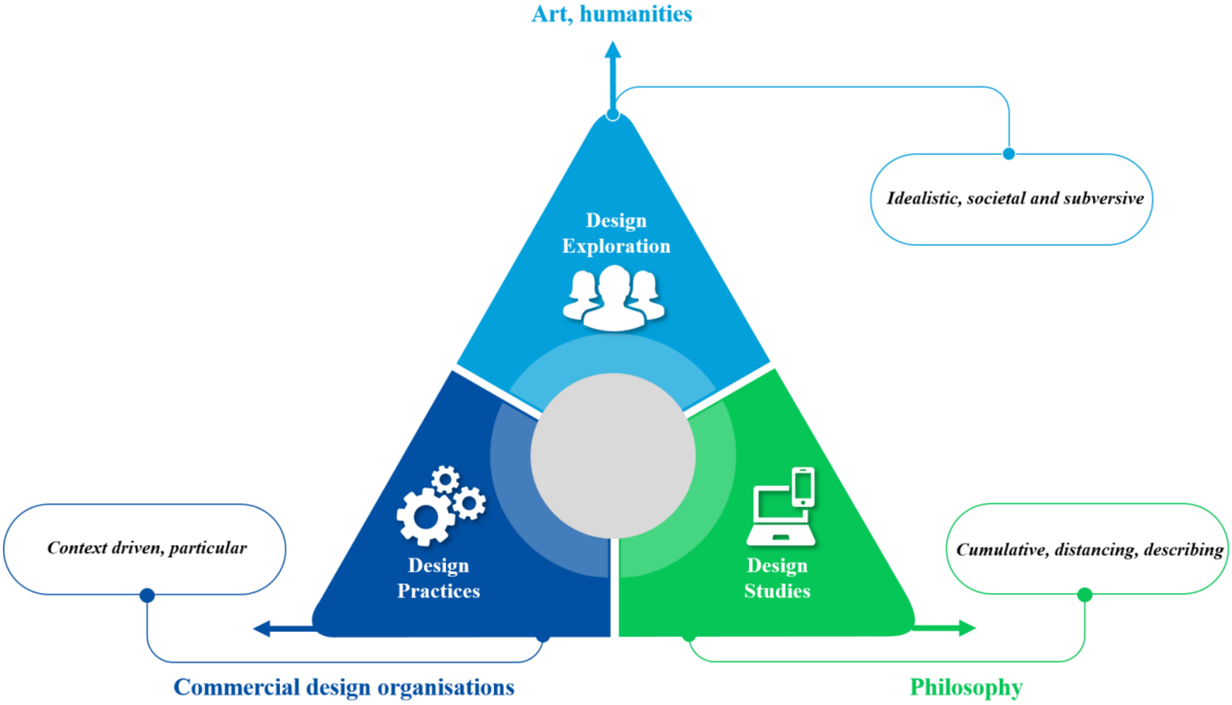

Figure 2: Triangle of types of design research [19]

The IoT technologies are moving from traditionally products/services, via smart products/services, smart connected products/services, products/services systems to system of systems. On this road the users experience needs several triggers to be engaged. The trigger experience indicators may vary from domains to domains. The document touches briefly on the five domains covered by the IoT European Large-Scale Pilots projects [22] e.g. ACTIVAGE - active and healthy ageing, AUTOPILOT - automated driving, IoF2020 - smart farming/agriculture, MONICA – wearables in the context of large-scale events, and SYNCHRONICITY – smart cities as the analysis can be extended later to IoT technologies and applications in other domains such as smart manufacturing, smart buildings, energy and other digital single market domains.

In **farming/agriculture** the return of investment is important. Examples on experience indicators for IoT technologies and applications that trigger the users are related to:

- Increased efficiency and productivity,
- Increased crops with minimal impact on the environment,
- Reduced rates of plant and livestock diseases, together with
- Less hazardous situations and reduced work accidents,
- Simplified everyday life, and
- Free up time.

The IoT technology (e.g. robots, drones, collar/tracking tags) equipped with sensors, cameras, monitors (e.g. VR, AR), actuators, wireless communication, and logging/computing capabilities (e.g. AI, autonomous system) enable smart precision farming/agriculture through observing, measuring and responding.

The experience level indicators are very important for the evaluation of **automated driving** and IoT technologies and applications. Trust as well as the attitude towards technology has been found to be an important precursor in the acceptance formation process. Conducting experiments with a driving simulator in order to investigate how the experience of automated driving changes the degree of trust in automation and the attitude of the driver towards automation indicated that the driving experience increased self-reported trust in automation and lead to a decrease in other measured constructs – such as safety gain. The participants drove highly automated on a three-lane highway at a speed of 120 km/h. As critical situations are expected to have a significant impact on trust in automation, the participants experienced three take-over scenarios (system limits) [10].

Vehicles are nowadays equipped with numerous interactive systems, aiding the driver by providing safety warnings, driving information, support, connectivity and entertainment. To ensure competitiveness, attention is now being further directed towards experiential values of the systems, collected under the umbrella term of "user experience" [11]. Several experience themes were identified for the in-vehicle systems in [11]:

- The vehicle as a caretaker – The participants enjoyed the feeling that the vehicle was taking care of their safety and needs, while also providing convenience. The experience of the caretaking vehicle was created through features such as the seat-belt tightening in sharp corners. Active safety and convenience systems were appreciated for saving the driver and passengers from dangers and inconvenience.

- The vehicle as a space for relatedness – The in-vehicle systems of the vehicle provided an opportunity for relatedness to other people, outside the vehicle, easily accessible through smartphone integration. Participants also connected to passengers in the car through shared in- vehicle activities, often enabled by the in-vehicle systems, such as listening together to music, podcasts or audio books.

- The vehicle as a space for stimulation – The discovery of new functions and the utilisation of the interactive systems available in the vehicle were a source of stimulation for the participants.
- The vehicle as a space for transition – Time spent in the vehicle was used as an opportunity to prepare for the next stage in the participants' lives. During commuting, the in-vehicle systems were thus an important part of the everyday life puzzle of activities, providing a window for reflection, planning and distancing. The use of the vehicle as a transitional space was accomplished for instance by preparing for work through taking work-related calls during the drive to work, and by catching up on e-mails, for example at traffic lights.

Three principal aspects of the findings were found to be formative for the long-term user experience of in-vehicle systems:

- Influence of other products - it was evident already from the start of the interview sessions that it was impossible to distinguish experience stories of the in-vehicle system from those that also concerned the participants' phones and other connective technology. All participants had in-vehicle systems that were connected to smartphones, and these units became intertwined from the users' viewpoint.
- Influence of new behaviours - new behaviours emerged over prolonged use. These new behaviours considerably altered the experience over time. Examples of such behaviours were the use of hands-free phone, working in the car and using apps for monitoring the car from home.
- Influence of social settings - a striking number of experience stories concerned social aspects of using in-vehicle systems, i.e. how they were experienced when in contact with other people. Only focusing on one person's solitary experiences of the technology would limit UX knowledge.

The results underscore that as it is not possible to give an informed evaluation of a product from initial, momentary use, it does not appear feasible to separate other products and people from the research of the user experience. There is thus a need for a methodology that can provide further understanding of these aspects. Values of the autonomous vehicle expressed by the participants at an experiment in Los Angeles by using the "Setting the stage for future automotive experiences" method to support user reflections on the temporal experiential dimensions of expectations is presented in Figure 3 [18].

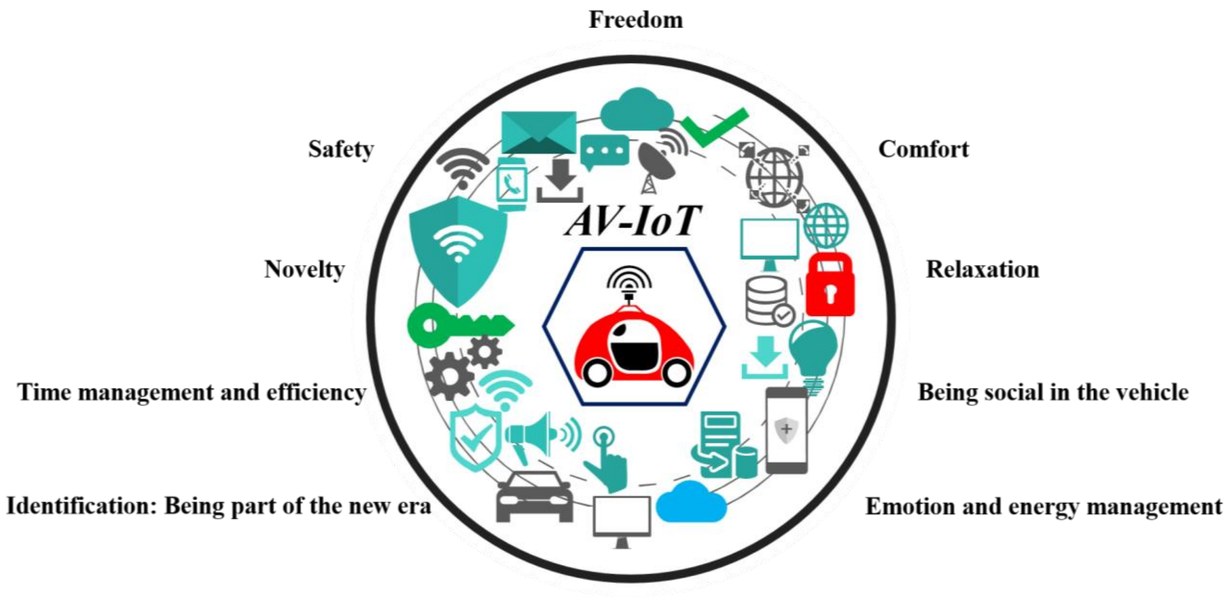

Figure 3: Values of the autonomous vehicle expressed by the participants [18]

Active and healthy ageing is human centric, and the return of investment is broadly defined. Examples on experience indicators that trigger the users (elderly, relatives, health services) are related to:

- Reduced social isolation.
- Increased cognitive stimulation.
- Increased level of activity/mobility.
- Become more self-reliant.
- Identify warning signals earlier.
- Increased feeling of security for both the elderly and their relatives.
- Replaced hospital/institution admissions with home care services.

Adapted elderly, IoT technologies like sensing wearables, cameras/monitors, robots and safety installations can enable services gaining active and healthy aging through observing, measuring and responding.

Wearables are electronic devices that can be worn on the body, either as an accessory or as part of material used in clothing. One of the major features of wearable technology is its ability to connect to the Internet, enabling data to be exchanged between a network and the device. Wearables interconnected with other wearables and other IoT devices are used in implementing IoT systems and applications across different business, consumer and industrial domains.

Wearables enhance the experience and participation and can be used in connecting people in large-scale sport events, concerts and public gatherings. The wearables market expands with 2-digit growth rates annually (according to an analysis by Gartner) with a potential for going from niche to a mainstream market. As wearables typically are personal products the market success depends on the ability to translate subtle consumer preferences to appealing wearable experiences [17].

A global IoT market is evolving around notions of **smart cities,** with businesses developing shared digital services which improve the lives of the citizens and grow local economies [21]. Creating a simplified, open and agile digital market across borders to help cities and its citizens to get better services while ensuring privacy, security and safety are needed to increase the user experience.

Examples of IoT supported applications and services are [21]: Human-centric traffic management where data-driven bicycle mobility stimulates bicycle usage by optimized cycling experience (flows, waiting times, safety) and improved infrastructure planning leveraging data from different sources throughout the smart city; Multi-modal transportation where public and private transportation modes are seamlessly mixed with new/shared mobility services to enable smoother, more reliable and pleasant choice of transportation modes while improving city quality of life; and Community policy suite where data-driven agile governance is incorporated in smart city management and policy making that cuts across vertical organization models and enhances local authority responsiveness and improve citizen engagement.

4.4 Experience readiness levels defined

The following ERLs are defined in the CREATE-IoT project:

- **ERL 1** – Basic principles for the product, service, experience, experience as a service based on consumer culture analysis in IoT area and end-user perceptions.
- **ERL 2** - Design of experimental elements and experience concept formulated for different IoT applications. Definition of experience as part of the IoT product and services offerings. Experience analysis suite in support of component technology development.
- **ERL 3** - Experimental proof of concept identifying the experience embedded in IoT applications. Human-system and machine-system interactions to include hardware and software), refining experience requirements thresholds.

- **ERL 4** – Experience validated in laboratory and virtual environments. Co-creation of perceived experience with expert consumers and end-users. Components of human and machine touch point engineering parameters and experience performance indicators.
- **ERL 5** - Experience validated in relevant IoT environment (industrially relevant environment in the case of key enabling technologies). Co-creation of experience with IoT applications.
- **ERL 6** - Experience demonstrated in relevant IoT environment and industrial sectors. End-user evaluation and consumer real-time tests and collective experience exchange. Field relevant environment validation of experience for system prototypes.
- **ERL 7** – Consumer and end-user driven IoT experience based on IoT system prototype demonstration in operational environment in different industrial sectors.
- **ERL 8** – System experience completed and qualified across end-users and costumers in different market segments. Experience based evaluation of human and machine performance parameters.
- **ERL 9** – IoT system and application experience proven in real-time in operational and virtual environments. Actual IoT system proven through successful mission operations and human and machine experience.

4.4.1 Experience readiness level and the integration with art

A framework for product emotion, is described in [13] that brides the concepts of emotion and experience, and claim that products can be experienced on three levels, adding meaning and aesthetics to emotions:

- The aesthetic level: a product's capacity to delight one or more of the sensory modalities.
- The meaning level: assigned personality or other expressive characteristics, resulting in personal or symbolic significance.
- The emotional level: emotions that are evoked by a product.

The framework does not advise any specific methodology for researching product experience but suggests that experiences reach further than instant emotions into also remembering, anticipating and experiencing meaning retrieved from the product.

Another framework that addresses the aspects of experience originating from experiencing interactive products, therefore positioned in research on human-machine interaction and cognitive science, is presented in [16] and distinguishes between the "why, what and how" of the interaction with a product.

The *why* addresses people's higher motives for using an artefact, such as establishing relatedness with another person through a telephone call, the *what* looks at what specifically can be achieved with the product (e.g. make a call), and the *how* addresses how the interaction is enabled by functionality and design. User experience is defined "… a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service" [15], constituted along two product dimensions; pragmatic and hedonic qualities.

Pragmatic qualities of a product/service concern the "do-goals" of a product/service, that are the practical goals of interaction such as making phone calls, uploading documents on a web site, or interacting with IoT devices.

The other category of goals, the 'be-goals' of a product, concerns the hedonic qualities, such as offering aesthetic and meaningful experiences.

Six needs are identified as especially important for satisfying experiences, namely *relatedness*, *meaning*, *stimulation*, *competence*, *security* and *popularity*. This supports the understanding of the product/service, the context and the user as an individual as formative for the user experience.

Emotional, subjective and transformational aspects of experiences can play an important role in evaluation different IoT technologies and applications. Four threads of experience are defined in [12] based on the individual, subjective and contextual experience:

- The Sensual Thread: a user's experience connected to sensory engagement.
- The Emotional Thread: value judgments of the experience; whether positive or negative emotions are connected to the experience.
- The Compositional Thread: relationships between the parts and the whole of an experience.
- The Spatio-Temporal Thread: how the experience relates to the user's past, future and place where the experience takes place.

In addition to the four threads, six sense-making processes are defined that can be used to discuss experiences through a temporal lens.

The six steps of an experience are described in Figure 4 as anticipating (e.g. expectations the user has from previous experiences), *connecting* (immediate responses with little cognitive effort), *interpreting* (making sense of an experience in a more conscious way), *reflecting* (reflections on experiences by retrospect evaluation and examination), *appropriating* (relating the experience to past and future), and *recounting* (telling the experience to one self and others by storytelling).

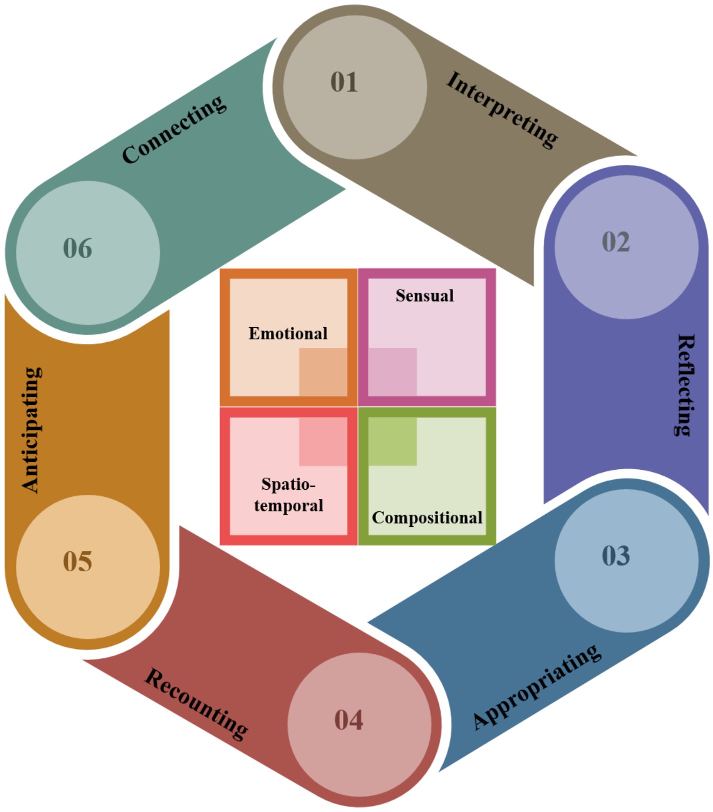

Figure 4: Technology as experience, adapted from [12]

However, few empirical examples exist of how these processes are experienced by users.

How you react to Artworks and the experience you have with Art has historically been in the domain of the Art community. The theory presented in [14] is an attempt to shift the understandings of what is essential and characteristic about the art process from its physical manifestations in the "expressive object" to the process in its entirety, a process whose fundamental element is no longer the material "work of art" but rather the development of an "experience".

The theory can be extended to IoT technologies and applications where products/services become processes of experience. The description of the actual act of experiencing is drawn

heavily from the biological/psychological theories presented in [14] and used for the development of functional psychology. In this context, sensory data and worldly stimulus enter the individual via the channels of afferent sense organs and that the perception of these stimuli is a "summation".

The ERL concept supports community of artists and IoT developers working together in order to invent and predict future uses and technologies while working in multidisciplinary teams and improving their agility.

One example is the Orange Art Factory where artists in residence worked with Orange employees on their projects, creating rich "cross fertilisation" experiences [20]. An example project might be Fabien Rocco' "Black Boxes", mysterious IoT enabled objects which are allowed to develop new relational interplay. Underwater connections – beginning to outline a new map of the world and the information that passes through it. In other words, a network in a forest where trees have a communication system that works on almost the same principle as the Internet, with signals transmitted from one tree to another. The communication communicated by the trees is emulated by a LoRa network and reproduced through a digital piece of artwork [20].

The CREATE-IoT project applied this concept by integrating an artist as part of VERTIGO residency. So Kanno, a Japanese artist proposed creating *"The ideal showroom of IoT". A*n object-related perspective allowed the artist to develop an experience-based show case for presenting elements need it in a trusted environment for the development of IoT and emphasizing the role of privacy, security and trust issues. Technology used for the project are IoT devices with hidden cameras, smart speaker systems, personal robots and VR technology. In the development of the art work, the consumer products are manipulated and adjusted for the artistic purpose [9].

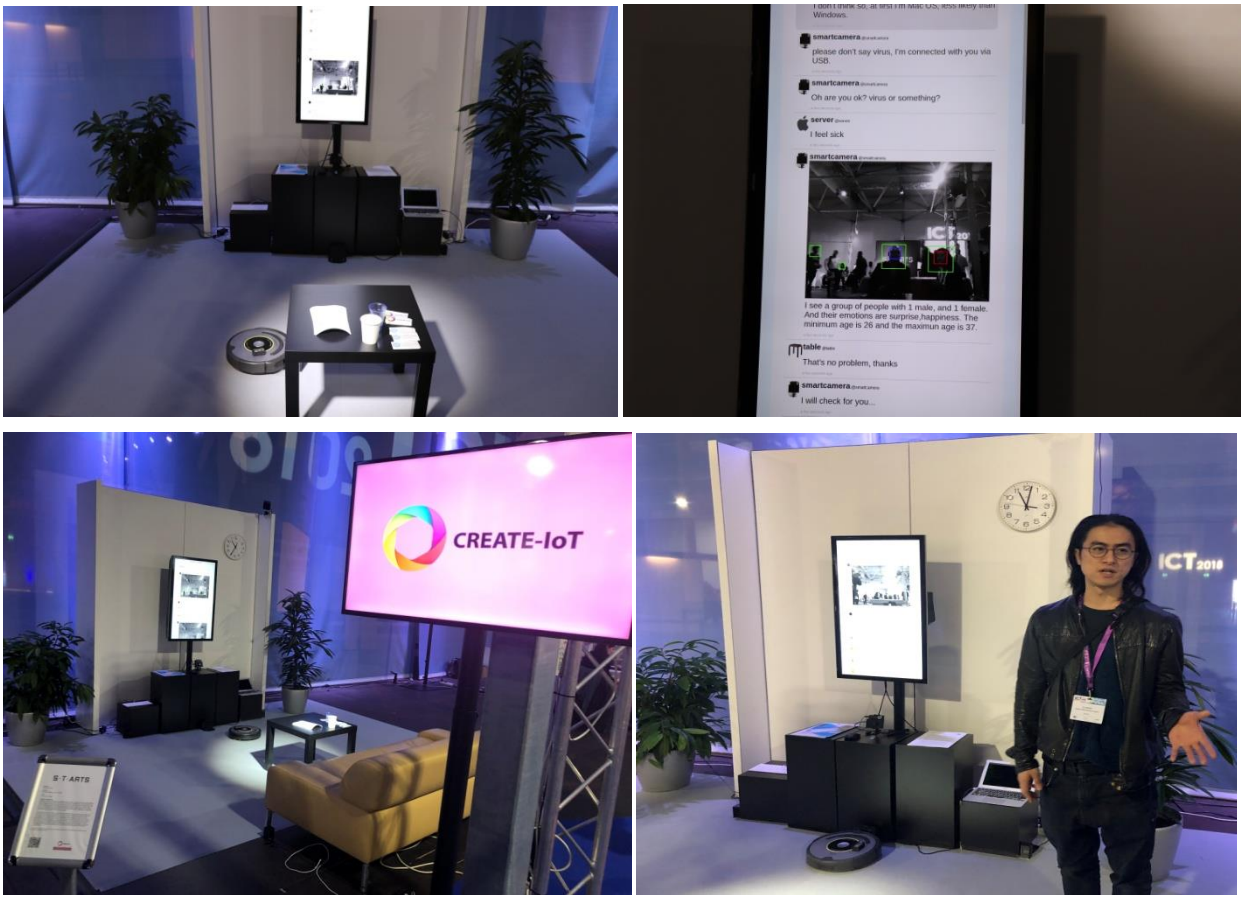

Figure 5: Show case - So Kanno - CREATE-IoT artist resident

As part of their activities, ARTS presented at the STOA (Science and Technology Options Assessment) panel on "Technology and the arts: Past, present and future synergies" on 17 January 2019 at European Parliament in Strasbourg the contemporary relationship between technology and the arts, predominantly concerning digital activities and discussed the role of experience readiness level from the arts perspective.

Figure 6: ARTS presentation at the STOA in Strasbourg

5. CONCLUSIONS

The IoT technologies and applications are deeply changing the way humans, machines and organisations interact with each other. Next generation IoT creates new ways for human-to-machines, machines-to-machines interactions in consumer, business and industrial applications.

The Experience Readiness Level (ERL) is a new notation that measures the capability of IoT systems to trigger a well-suited user experience. IoT user experience will play an important role in the future developments which include a wide variety of technologies and design interactions. The IoT user experience evolves and will depend on elements such as intelligent sensors/actuators, algorithms, experience architectures and context, and socially aware experiences.

The next generation IoT ecosystems will incorporate new technologies such as autonomous systems, AI, VA, VR, AR, wearables, distributed ledger technologies, edge commuting platforms, and the user experience will play a crucial role in assessing the maturity of IoT technologies and applications to create compelling, efficient, and fulfilling experiences in new IoT mediums, contexts and environments across industrial sectors.

This document proposes a novel ERL framework as a complementary practice to other, pre-existing, readiness levels frameworks that provide qualitative evaluation of the maturity of IoT technologies and applications, while ERL addresses a gap in this assessment landscape.

Further work will focus on identifying how readiness levels can be combined in the IoT world, where experience is a part of a service and hence a vital commercial incentive for effective development. In this context, extending the concepts of experience used in the domain of arts to IoT technologies and applications where products/services become processes of experience could support the idea that experience will become part of the business models for IoT technologies and applications.

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