INTRODUCTION TO THE SKILLS PROJECT AND ITS THEORETICAL FRAMEWORK

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Abstract: SKILLS is a FP6 Integrated Project dealing with the acquisition, interpretation, storing and transfer of human skill by means of multimodal interfaces, Robotics, Virtual Environments (VE) technologies and Interaction Design methodologies. SKILLS intends to introduce a novel approach to skill capturing, transfer and assessment based on enactive paradigms of interaction between the human operator and the interface system devoted to mimic task conditions. SKILLS promotes (i) enactive knowledge and enactive training, (ii) during skill acquisition and transfer, (iii) relying on intrinsic, affordance-based metrics, and using (iv) technological interfaces as accelerators, (v) available to multiple users (trainees, trainers). We provide examples showing how each of these concepts influences our perspective and can be translated into concrete actions in research and innovation.

Key words: Virtual environments, skills transfer, skill capturing, affordances, enactive training.

1- Introduction.

The SKILLS European project (FP6, #035005)[1] addresses the development of new methodologies for the acquisition and transfer of human skills by means of multimodal interfaces. The acquisition, interpretation, storage and/or simulation of sensori-motor and cognitive skills by means of multimodal interfaces and virtual environments technologies are becoming increasingly used for training, in application domains as diverse as Industry, Surgery, Automotive, Sport, Entertainment, Cultural heritage, etc…. In all these and other areas, the *speed*, *efficiency*, and *transferability* of training are three major requests from our contemporary societies that have progressively driven the development of technological (multimodal) interfaces. Technological development in this area often follows fundamental research on human skills, learning, cognition, perception and action, but sometimes emerges on the market out of empiricism and intuition. In all cases, training procedures are developed to facilitate learning, and imply observing a model, establishing adequate representations of movement sequences and motor responses, transforming specific instructions into appropriate movements, extending simple sensori-motor schemes to new and more complex conditions, or transferring skills from one situation to another.

To successfully reach its goal, the project requires the integration of research activities (RA) embedded into demonstration activities (DA). Figure 1 summarizes the structure of the project. Research activities involve the fundamental mechanisms underlying skilled behavior, the acquisition and training of skills (RA1), the digital implementation of skill and training components (RA2), the

[1] *www.skills-ip.eu*

capturing procedures of the components using adequate capture technologies (RA3), and the multimodal rendering of the skill components using adequate rendering techniques (RA4). Three areas of demonstration have been identified, including sport and entertainment (DA1), surgery and rehabilitation (DA2), and industry and manufacturing (DA3). Seven specific demonstrators have been selected, on which effort of skill integration are performed: Juggling (JUG), Rowing (ROW), Maxillo-Facial Surgery (MFS), Minimally Invasive Surgery (MIS), Upper-Limb Rehabilitation (ULR), Programming by Demonstration (PbD), and Industrial Maintenance and Assembly (IMA). Details about the SKILLS demonstrators can be found in a joint paper in these proceedings. [GC1]

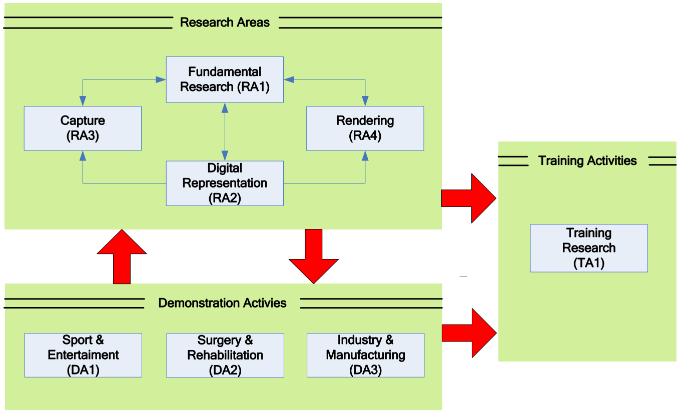

Figure 1. The general structure of the SKILLS European project.

The SKILLS project relies on a set of fundamental assumptions. Taken together, these assumptions constitute the signature of the project and can be visible in a way or another in all demonstrators. Here we briefly present a prototypical example in the field of industrial maintenance, in the form of a *story-telling* scenario, to illustrate in a concrete way some of the main questions addressed in the SKILLS project. We then provide a formal definition of skill before outlining the theoretical foundations and some of the main challenges the project offers for research.

1.1 - A prototypical industrial scenario.

Ralph and John are two technicians working for the Central America Beverage Corporation Company (CABCORP) bottling fruit juices in a Guatemala plant. Ralph has just begun to work for CABCORP, while John has already 3 years of experience. Ralph is acquainted with operating mechanical devices, but it has not yet received any specific technical training on the machines of the plant, while two years before John has been sent two weeks in France to participate to a training course organized by the machines supplier. During the course, John has been instructed about the internal structure of the machines, the working principles, how to operate them and how to perform the most important maintenance tasks.

Given the size of the machines and of a real plant, only a very small number of non-operative mock-ups were present at the training facilities making it impossible to perform extensive on-the-job practice, so that most of the notions provided were purely theoretical. John brought back from the course several manuals that ware supposed to help him not to forget what he has learned, but he rarely uses them.

Figure 2. A story-telling industrial scenario illustrating the SKILLS research questions.

One day, John and Ralph's company receives from the machine supplier a new training tool based on Augmented Reality (see figure 2). With this tool, it is possible for the two workers to perform on-the-job training directly in the plant and on the real machines. They will be able to get enactive training on the procedural skills needed to perform maintenance tasks in each of the machines. Also, it will not be any more necessary to travel to France to attend courses, as the supplier trainer will be connected remotely to teach how to operate and repair the machines directly inside the plant. Finally, now every single machine can be used for training classes, even the custom models that the machine supplier built on purpose for CABCORP.

The AR training system is a sophisticate piece of equipment. It does not only provide visual information of the machines, but it is equipped with various multimodal capturing and rendering technologies, in order to maximize the effectiveness of the communication between the trainer and the trainee. The AR training system makes it possible to train Ralph and John on something that both are missing: direct manipulation of the machines, i.e., learning by doing. Training is individual, and it takes in account the fact that Ralph is a complete novice, while John is acquainted with the basic notions about the machines.

In their first session, both technicians are trained in maintaining the electronic actuator of a motorized modulating valve. The intervention is to replace a broken part. Each of them has to disassemble the valve from the machine, then disassemble the valve to replace the broken part, and finally re-assembly the valve. This is done directly inside the plant and on the real machine. In this session each trainee is connected on-line with Susan, an expert trainer in these tasks.

Using the system, the trainee can be guided using a carefully chosen mix of visual, audio and haptic feedback, designed to guide movements and action sequences in the most efficient and secure way. With this training, the trainee can learn both the correct sequence of actions and the movements to be done, and improve the procedural skills. In addition, Susan can feel the movements and actions made by the trainee to evaluate his performance and correct him if necessary. By directly operating the real machines with their own hands, both John and Ralph acquire confidence in their training, and have no doubt anymore that what they have learned will be applicable to their specific case.

1.2. Behind the scenario.

The AR platform developed in this demonstrator allows the user to learn new knowledge by doing and getting on line relevant information about the discrepancy between what to do and what is being done. An important feature of this scenario is its "flexibility", i.e., its adaptability to the context, the needs, and the preferences of the learner, and from initial passive strategies to more active ones. Examples of active strategies include the specific combination of different sensory modalities throughout the training process, the progressive ability to use the skill captured from an expert and stored in a digital database, or to use a direct transfer from the expert. The present trainer is directed for the use of technicians who need to learn new tasks or work with a new machine. The most important skills to be acquired in this scenario are the complete and smooth performance of procedures. The uniqueness of the AR system is in giving the trainer new and powerful tools for instruction as well as receiving information about the trainee.

2- Definition of human skills.

SKILL can be generally defined as the capacity acquired by learning to reach a specified goal in a specific task with the maximum of success and a minimum of time, energy or both (e.g., [S1]). This simple definition suggests that skill cannot be considered as a general ability, but rather as a specific learned capacity. A number of criteria can be analyzed for evaluating the level of skill, and have to be integrated in a formal definition of skill. Four of them are listed here.

1. The accuracy of the outcome, with respect to the assigned goal: this criterion is the most commonly used in behavioral approaches to learning, and measured in terms of errors to the target goal (spatial and /or temporal).

2. The consistency of responses over successive trials represents another important criterion. Skill allows producing effective behaviour in a stable and reproducible manner. Consistency can be measured by assessing the standard deviation of a set of successive outcomes. Recent approaches focus not only on the amplitude of variability but also on its structure in time (e.g., [KS1]). For instance, numerous studies have suggested that unskilled behaviour fluctuates randomly over time while skilled behaviour presents a very special kind of fluctuation, called "1/f noise", characterized by a complex set of correlations among successive measures.

3. Efficiency, i.e. the fact that the goal is usually reached with a maximum of success and a minimum of expense, is also a fundamental component of skill. Efficiency can be understood at the cognitive level (skill is associated with the use of automatic processes allowing a decrease in mental load), and at the metabolic level (the skilled behaviour allows reaching the goal with a reduced metabolic cost). Cognitive efficiency and metabolic efficiency usually go together.

4. Skills are also conceived as flexible and adaptive: Skilled behaviour should be able to cope with environmental irregularities and uncertainties. This flexibility is related to the intrinsic (structured) variability of the skilled behaviour discussed in point 5 below. This flexibility suggests that skill is not specific to a particular task, but, rather, to an ensemble of similar tasks. This question emphasizes the fundamental problems of skill generalization or transfer. Flexibility and adaptability are important aspects. They are often producing behaviours that appear variable. But variability here is functional. It should not necessarily be viewed negatively (as reflecting noise for instance) but as a reflection of the readiness or plasticity of the system to change. Different variables can be used to separate negative variability (noise) from positive variability (adaptability).

3- Research challenges and theoretical foundations.

As said above, the SKILLS project concentrates on a set of (four) fundamental assumptions that offer new directions for research in sensori-motor and cognitive control of action. We now review them in turn.

3.1 - Skill acquisition and transfer using multimodal interfaces.

Acquisition and transfer of learning are central to understand how we develop general competencies. It is especially important in the SKILLS project to understand the kinds of learning experiences that lead to transfer. Transfer is defined as the ability to extend what has been learned in one context to new contexts. In general, trainers hope that trainees will transfer learning from one skill to another, from one period to another, from one situation to another. Measures of transfer play an important role in assessing the quality of people's learning experiences. Different kinds of learning experience can look equivalent when tests of learning focus solely on end-of-acquisition performances (e.g., on the ability to achieve learned performances), but they can look quite different when tests of transfer are used, for instance transfer from simulated practice to real practice, or from one task to another. In the SKILLS project the first fundamental assumption is that the use of multimodal interfaces (virtual reality systems, augmented reality systems, robots), used in appropriate training situations, can accelerate the learning and stabilization of new skills. Testing this assumption requires controlled comparisons between performances executed after practice in the real environment and after practice in the interfaced environment. Important research questions in SKILLS demonstrators thus concern (i) the skills element that are acquired and transferred, (ii) the amount of initial expertise that is necessary for transfer, (iii) the type of knowledge (contextualized, abstract) that promote learning and transfer, (iv) the type of fidelity required from the interface that promote transfer, and (v) the type of training procedures that facilitate learning and transfer.

3.2 - Enactive learning and training.

There are many ways by which we can learn a new skill. We can learn by observing a model, by reading instructions, by listening to the coach, and of course by practicing ourselves. In the SKILLS project, the idea that we learn mostly by doing is pushed very far. It does not mean that other forms of learning are not important, and it does not mean that learning by doing is incompatible with other ways of learning. But it does mean that training for the acquisition of new knowledge is obtained primarily through a guided active interaction of the learner with the environment [G1], a form of knowledge that is called enactive knowledge [VT1], a form of learning that we call enactive learning, and a form of training that we call guided enactive training. The appeal to concentrate on guided enactive knowledge is that it is direct, intuitive, fast, embodied into common action-perception behaviours, and that it may be — an hypothesis that will be tested during the course of the project — more efficient than other types of training procedure for becoming an expert. One consequence for the SKILLS project, as illustrated by the introductory scenario, is that multimodal interfaces are used to enact high-level symbolic representations that are known to be important for skill acquisition, and to represent them in action-perception languages instead of manuals of detailed verbal instructions decoupled from the action itself.

In the selected demonstrators, the technology developed among partners of the consortium is used to facilitate the interaction between the learner and the (digital or real) environment, and to facilitate the interaction between the learner and the (digital or real) instructor, in the most direct and univocal way. Research questions that concerns the enactive aspects of the SKILLS project thus relate to (i) the embodiment of cognitive strategies, intentions, or feedbacks during skill acquisition, (ii) the representation of training procedures in an enactive language, (iii) the advantages of skills enactive learning & training over other procedures (iv) the functional skill fidelity of our interfaces (action fidelity), as apposed to their experiential fidelity (subjective fidelity or presence).

3.3 - Multisensory interaction.

In general, behaviour produces simultaneous changes in multiple sensory systems. For example, drilling a bone in surgery or juggling produce changes in the stimulation of the visual, vestibular, auditory, and somatosensory systems. This is true for all demonstration activities in the SKILLS project, as it is true in daily life. Even the most elementary and pervasive acts, such as breathing or controlling posture, produce changes in the stimulation of multiple perceptual systems. The multisensory consequences of behaviour have fundamental implications for the nature of perception. Perception, we argue in the SKILLS project, is never unimodal. It is always multimodal and intermodal, even when attention is targeted onto on modality or when technology is used to provide modality-specific feedbacks. Some modalities can be temporarily turned off, such as the visual system when we close our eyes, but others cannot, such as the somato-sensory system. Even when one modality is not stimulated, the relation that this modality has with the other modalities continues to exist. Changes within different forms of ambient energy, and therefore within different modalities, are not independent of one another; rather, they are interrelated; they are congruent with each other. These interrelations constitute higher-order patterns that extend across different modalities (see [SB1] for a full treatment). Compatible with this position is the growing body of neurophysiological evidences that the nervous system is not organized in a sense-specific fashion, but contains many structures that respond to activity originating in more than one sense modality. How the senses cooperate when interacting with a multimodal interfaces and how this cooperation changes during the course of learning is a theoretical challenge in the SKILLS project. Specific research questions therefore refer to (i) the change in congruency of multi-sensory stimulation during skill acquisition, (ii) the integration of modality-interfaced sources of information into a unitary perception, (iii) the manipulation of modality-specific information during learning when interacting with the interface, (iv) the inclusion of modality-related training protocols to accelerate learning and stabilize transfer, (v) the influence of alternative structures of enacted experience on the acquisition of skills and their final format, (vi) the effect of manipulating performance objectives on the learning and final format of the skills.

3. 4 - Perception and control of affordances.

Metrics are important matter for skill acquisition and transfer. A metric is a standard unit of measure quantitatively and periodically measuring, assessing, or controlling behaviour. Behaviour generally consists of interactions with the environment. In the case of multimodal interfaces, behaviour consists of interactions of the user with the interface, or with virtual environments through the interface. The success of behaviour (i.e., here acquiring skill) is constrained by relations between the agent and the environment. A classical example is climbing stairs, where the maximum stair height that can be climbed is not an absolute quantity (e.g., 1.2 meters) but, rather, a relational quantity (for healthy adults, 88% of leg length). Affordances are these relational quantities; they are properties of the agent-environment system that constrain behaviour [G1; S2; W1]. They are properties of the environment scaled in commensurate properties of the agent. They are defined at the functional level by relative metrics about action opportunities (e.g., catchability, reachability, etc…), not by absolute metrics (e.g., seconds, meters, of joules). Affordances constrain what behaviours are possible in a given environment/situation, what behaviours are easy/hard, efficient, inefficient, and so on. Affordances cross the sensori-motor and cognitive levels of analysis. Given their influence on behaviour, it is useful for behaving agents to know about the affordances that are available to them. In the SKILLS project, we deal with novices and expert agents. Affordances are different for novices and for experts, i.e., behaviours that are possible for experts may not be possible for novices. More generally, non-linear changes in behaviour during skill acquisition and transfer are accompanied by corresponding changes in relevant information used to control finer and more complex behaviours. When considering intentional, voluntary behaviour the term "performance alternatives space" is used to convey the same meaning as affordances. The performance alternatives space encompasses all behaviour alternatives available for a performer on a task given his abilities and level of expertise [EG1]. With the progress of skills, new response alternatives are added to the space and the cost of performing many existing alternatives reduces. For example, with the acquisition of juggling skills performers may be able to advance from 3 to 5 to 7 balls tricks, while the effort of performing 3 and 5 balls tricks decreases. Interface design in the SKILLS project focus on the acquisition and presentation of information about the actions and response alternatives that are available to users, that is, to the availability alternatives and affordances of the controlled system. The scenario described in the introduction reveals that information important at stage N and at stage N+1 are different, because they rely on different agent capacities. In juggling, a ball that is not catchable at stage 1 becomes catchable at stage 2 with learning. During maxillo-facial surgery, the spine may be haptically findable at stage 2 but not at stage 1 of learning, due to sensitivity of the haptic system to relevant information. During industrial maintenance, more parts of the machine may be assemblable at stage 2 than at stage 1, due to the procedural knowledge of assembling rules by the learner. Our multimodal interfaces in the SKILLS project are designed to scale appropriate information relevant to skill acquisition to the sensori-motor and cognitive capabilities of the trainee. This call for an affordance-based design of multimodal interfaces raises a number of fundamental questions, among which (i) the definition of skills components and performances in functional terms (e.g., action-related), (ii) the characterization of relevant affordances on which demonstrators are built, (iii) the evaluation of the changes in affordances as learning progresses, and (iv) the role of affordance in training programs.

The four theoretical assumptions outlined here bring to the front important research challenges within the SKILLS framework. These questions are testable using appropriate methodologies coming from the field of experimental psychology and motor control. They are currently submitted to experimental validation by researchers of the consortium. A fifth and more technological assumption, i.e., that skill can be digitally represented in order to allow a rapid transfer, is described in the next paper [AR1].

4- Sub-skills.

Central to the demonstration skills (e.g., juggling, rowing, etc…) briefly mentioned here and in other accompanying papers [AR1, GC1] are the various skill elements, or sub-skills that compose them. Roughly, sub-skills can be divided into sensorimotor and cognitive components. In general, sensorimotor sub-skills are targeted onto the reciprocal relation between perceptual and motor elements, and cognitive skills are related to higher-level activities that orient, formulate, or monitor the sensori-motor performance.

4.1 - Sub-skills and enaction.

The above distinction is, however, partly arbitrary and the two categories are largely interdependent. This is because of the natural embodiment of cognitive phenomena into sensori-motor dynamics, an embodiment at the heart of the SKILLS project. Although there are several views on embodied cognition (see [W2] for a review), the term refers to the basic fact that a) cognition is largely for action, and b) off-line cognition (cognition decoupled from the environment) is largely body-based. Consistent with these claims is the fact that perceptual inputs (e.g., vision) can elicit covert motor representations in the absence of any task demand. For example, judgments of whether a screwdriver is screwing or unscrewing are faster when the orientation of the handle is consistent with the manual dominance of the observer [DS1]. There is also increasing evidence coming from brain imaging studies that the perception of objects automatically affords actions that can be made towards them [GT1]. Similarly, the fact that when individuals observe an action, an internal replica of that action is automatically generated in their premotor cortex [BB1], suggests that embodied cognition plays a role in representing and understanding the behavior of conspecifics [W2], such as in learning from imitation for the acquisition of enactive knowledge. Likewise, the perception of actions seems to be mediated by embodied processing. Hence perception is not solely a visual or auditory or tactile process, preceding symbolic representations of actions to be performed. What one perceives in the world is influenced not only by, for instance, optical and ocular-motor information, but also by one’s purposes, physiological state, and emotions. Perception and cognition are embodied; they relate body and goals to the opportunities and costs of acting in the environment [G1, 1979; P1]. The enactment of perception-action and cognitive sub-skills using adequate technologies is an important challenge of the SKILLS consortium. In the next two sections, we list the major sub-skills selected for the project. Appendix 1 provides more information about each of these sub-skills.

4.2 - Sensori-motor sub-skills.

Although different perceptual modalities and different types effectors are involved in the SKILLS project and the various demonstrators, the sensori-motor and related cognitive sub-skills described here are general, abstract, and well-documented components that underlie most (if not each) of them. Among a virtually infinite number of sub-skills that compose human activities, they have been selected because of (i) their key importance for the successful achievement of the skilled performance, (ii) their possible yet challenging enactment in the various demonstrators of the project, (iii) their coverage of complementary perceptual modalities or effectors, (iv) their visible evolution over time and learning, and (v) their anchorage in a solid state-of-the-art in basic human movement and cognitive sciences.

- Balance and posture control
- Bimanual coordination
- Hand-eye coordination
- Interpersonal coordination
- Perception-by-touch
- Prospective control
- Proximal-distal coupling
- Respiratory/movement coupling
- Fine force control

4.3 - Cognitive sub-skills.

The ensemble of cognitive skills refers to the efficiency of perceiving and encoding task relevant information from the environment; the level and quality of storing, organizing and maintaining it in long-term memory and the efficiency of accessing it upon demand. Cognitive skills can be subdivided into two major categories:

1) Those associated with the encoding representation and storage of information

2) Those associated with the usage of this store when responding to environmental demands and in the conduct of intentional, goal directed behavior.

Presented below is a list of the most important cognitive skills involved in the various demonstrators of the SKILLS project.

- Control flexibility and attention management skills.
- Coping strategies and alternative response schemas.
- Memory organization, structure and development of knowledge schemas.
- Perceptual Observational.
- Procedural skills.

5- A general picture.

Sensori-motor and cognitive sub-skills are thus the heart of the SKILLS project. Research on these skill elements in the context of multimodal interfaces not only provides interesting knowledge about how humans learn new movements under appropriate guidance. It provides specific instructions to trainers about the training strategies to adopt for their trainees, the type of (body-scaled) information to render, the motor components to focus on in priority, etc… It of course also provides important knowledge to interface designers about the mechanisms of human learning in a technological environment.

Figure 3 below summarizes the general picture of the project. The left part recalls the four theoretical challenges identified as key challenges when dealing with acquisition and transfer of skill using multimodal interfaces. The mapping between these challenges and the sub-skills identified (SSK), together with the training instructions (Tr), are core aspects to be investigated by fundamental research in movement and cognitive sciences. The right part of Figure 3 recapitulates the seven demonstrators of the project, nourished by the scenarios in the form of the one described in the introduction. The mapping between the fundamental part of the project (left) and the seven demonstrators (right) will contribute to the development of a new generation of multimodal interfaces devoted to the acquisition and transfer of skill.

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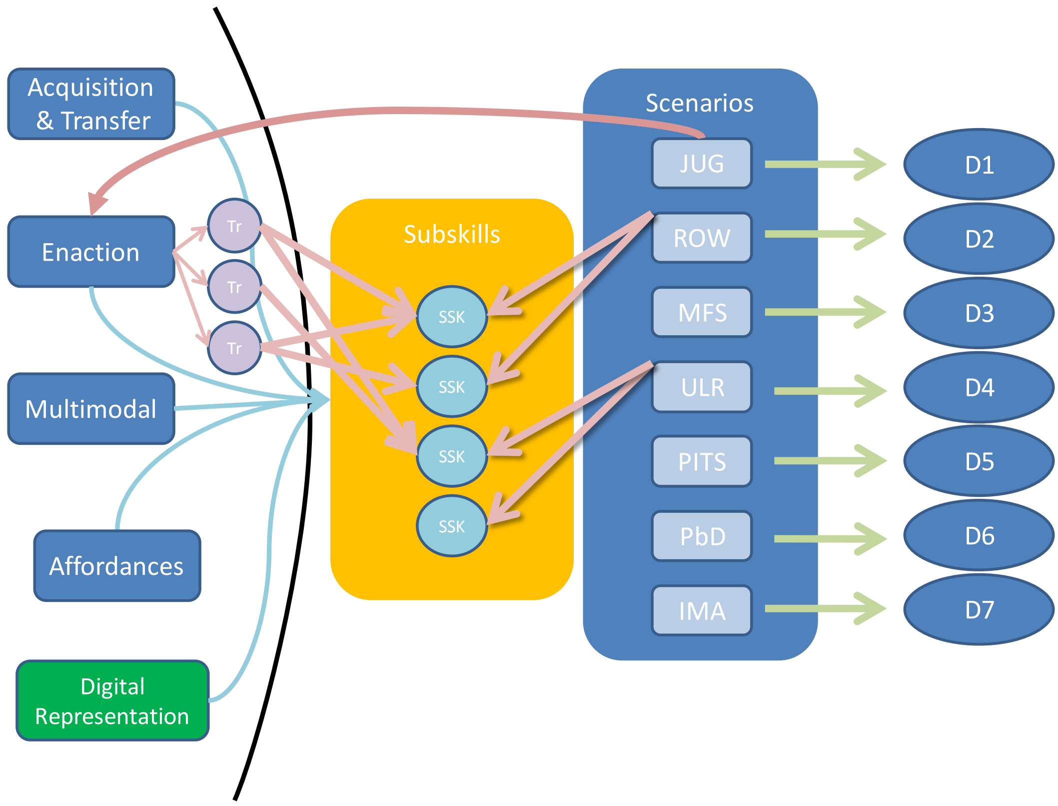

Figure 3. A general sketch of the SKILLS project showing the mapping between research challenges and demonstration activities.

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8 – Annex 1: Details of sensori-motor and cognitive sub-skills

Sensori-motor sub-skills	
Balance and postural control	The regulation of posture (segments, muscles, joints, etc…) and balance (static, dynamic, standing, sitting, etc…) that allows the distal/manual performance to be successfully achieved. It is captured by inter-segmental and inter-muscular coordination, as well as center-of-pressure variables
Bimanual coordination	The functional synchronization in space and time of the arms/hands/fingers. Bimanual coordination is captured by the relative phase between the coordinated elements, its stability, and well as by relaxation time variables.
Hand – eye coordination	The synchronization of eye / gaze / effector with reference to the main information perceptually detected. It is assesses by gain, relative phase, and in general coupling variables between eye, gaze, and hand (and stability).
Interpersonal coordination	The coupling between two or more persons. It emerges from a multilevel nexus of components including sociality (interaction with social goals increases the degree of coordination), motor dynamical principles (rhythmic entrainment of co-actor), and neuroscience constraints (mirror systems). It is assessed by the relative phasing between persons.
Perception-by-touch	The coetaneous component of the haptic modality. Various receptors embedded in the skin provide information about mechanical properties (*vibration*, *compliance* and *roughness)*, *temperature* and *pain*. It is evaluated by psychophysical methods using absolute and relative thresholds as variables
Prospective control	The anticipation of future place-of contact and time-to-contact based on spatio-temporal information contained in optic, acoustic, or haptic energy arrays. It requires the coupling between movement parameters and information contained in various energy arrays, and is measured by time-to-contact and related variables.
Proximo-distal coupling	The spatio-temporal coordination of proximal, gross, posture-based components with distal, fine, and manipulatory components. It can refer to the organization of the body underlying arm movements, to the synergy between arm postures and hand movements, or for instance to the stabilization of the head and torso with respect to the distal component. It is assessed by cross-coherence, cross-correlation, relative phase between proximal and distal movements.
Respiratory-movement coupling	The synchronization of breathing and movement (segments, muscles, joints, etc…) that allows efficient performance. It is measured by amplitude, phase and frequency synchronization patterns (and their stability).
Fine force	The online regulation of the internal forces

control	applied on the surface to successfully reach the goal (drilling, pasting, navigating, etc…). It depends on the properties of the surface in relation to the forces developed by the effector, and is evaluated by the ratio between the two.

Cognitive sub-skills	
Control flexibility and attention management skills	The ability to change response modes and performance strategies, to apply and manage new attention policies in order to cope with task demands and/or pursue new intentions and goals. They are measured by adjustments to changes in task demand, attention allocation, and arsenals of strategies
Coping strategies and response schemas	A vector of importance or attention weights computed over the many sub-elements of a task, which are associated with the achievement of a specific goal. Each way to reach the goal represents a strategy. When highly automated, strategies become response schemas, i.e., integrated responses triggered by single commands. Measured by the number and type of strategies to cope with variations in task demands and changes of intention.
Memory organization, structure and development of knowledge schemas	Level of formulated and organized multi hierarchy, task specific memory and knowledge bases that facilitate encoding, retrieval and the conduct of performance. Measured by speed and accuracy of encoding, response and decision making performance, and number, diversity and speed of generating alternative solutions.
Perceptual Observational	The ability to detect, sample and extract task relevant information from the environment and perceive static patterns and dynamic regularities. Measured by sped, efficiency, amount of conscious supervision, and use of higher level structures and redundancies.
Procedural skills	Sequences of ordered activities that need to be carried out in the performance of tasks, the same procedure had to be repeated every time the same task segment is performed. Performance of every task can be subdivided into a large number of procedures, the competence in the performance of which is developed with training. Evaluated by speed and efficiency of performance, type of supervision (un/conscious).

Annexe 2 – The SKILLS consortium

Name	Short Name	Country
Scuola Superiore di Studi Universitari e di Perfezionamento Sant'Anna	PERCRO	Italy
Fraunhofer-Gesellschaft zur Förderung der angewandten Forschung e.V.	FhG	Germany
Commissariat à l'Energie Atomique	CEA	France
Université Montpellier-1	UM1	France
Deutsches Zentrum für Luft- und Raumfahrt e.V.	DLR	Germany
Fundaciòn LABEIN	LABEIN	Spain
Centro de Estudios e Investigaciones Técnicas de Gipuzkoa	CEIT	Spain
Israel Institute of Technology	TECHNION	Israel
University of Tampere	UTA	Finland
Queen's University Belfast	QUB	United Kingdom
KUKA Roboter GmbH	KUKA	Germany
Aalborg University	AAU	Denmark
Haption S.A.	HAPTION	France
OMG	OMG	United Kingdom
SIMONAZZI	SIMONAZZI	Italy