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Deliverable D6.2/D26: Final mock-up version of REACH system (associated with task T 6.2)

Abstract: In REACH, WP6 focusses on systems engineering and testing aspects such as system integration, verification, validation, and optimization. The presented Deliverable (associated with Task **T6.2**) provides a presentation/demonstration of the executed trials including different partner groups in different use case settings. It is worth mentioning that since this deliverable report has a nature of "Demonstrator", this document tries to show the implemented trials. Therefore, it was tried to integrate as many pictures as possible to prove the trials. This deliverable report targets mainly the Touchpoints **TP1**, **TP2** and **TP3**. This is decided due to the person months of the partners involved in this task. In these trials the partners addressed a pre-integration of sub modules involved in the future REACH presentation. Additionally, this deliverable discusses the trials from the first step which is the planning and execution, then to the execution/implementation and then to analysis and studying the results. Furthermore, using these trials the deficiencies and shortcomings were identified in these lab experimentations. Early detection of shortcomings and deficiencies will lead to simplified implementation and adjustment before reaching the final testing and integration stages. At the current time, the partners are already planning and preparing for the future tests/trials at the use case settings sites.

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Participants:	TUM; Tu/e; AM
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Tasks of the involved partners with respect to the deliverable (and respective tasks) presented in this report:

Partner	Short task description
TUM	• Defining task scope • Leading the task • Coordination and communication between partners for individual contributions to this task • Writing and finalizing this deliverable report • Taking part in the trial execution at br2 • Preparing the laboratory for the trial • Developing and mounting sensing system into the test apartment • Supporting partners in proper data collection for the machine learning algorithms and for ethics commission application
AM	• Participation and implementation of a trial at ZZ use case setting including the use of the activLife device • Implementing a study on several physical criteria to compare use of the activLife module for rehabilitation to normal physiotherapy • Statistical analysis of the results from the trial and considering using the activLife device vs the physiotherapical methods
Tu/e	• Participating and implementation of trial at ZZ use case setting • Investigating how to personalize motivational strategies • Collection of personal, psychological, contextual and behavioral factors for personalized motivation methods • Observation of the extent to which the people changed their behavior when exposed to different motivational strategies

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Key expressions

Abbreviations for partners:

AH: ArjoHuntleigh
AM: Alreh Medical
CU: University of Copenhagen
DTU: Technical University of Denmark
EPFL: École Polytechnique Fédérale of Lausanne, Switzerland
HUG: Hôpitaux Universitaires Genève
PSS: Product Service System
SC: SmartCardia
SK: Schön Klinik
TU/e: Eindhoven University of Technology
TUM: Technical University of Munich
ZZ: ZuidZorg

ActivPAL Sensor: The activPAL is the world's first single-site instrument that is validated to quantify postural allocation. It is the researcher's preferred choice for quantifying free-living sedentary, upright and ambulatory activities, providing the evidence to link sedentary behaviors to chronic disease risk. The small, lightweight device is worn discretely on the subject.

Agile project management: Agile project management is compared to the V-Model approach a more flexible and versatile approach for project management including systems development/integration. In contrast to the V-Model approach it builds on a continuous iteration loop between development and testing (**InLoox, n.d.**).

D: Deliverable report.

Data Collection: the process of gathering and measuring information on targeted variables.

Decomposition of testing approach: For each Touchpoint separate testing parts/instances (early detection, motivational techniques, and programmed interventions) were created and each of this testing instances represents a separate trial with an own hypothesis, own outcome measures, and an instance specific trial design.

Early testing: small user feedback and iteration loops to develop qualitative features

ELAN: A professional tool for the creation of complex annotations on video and audio resources.

Engine: The "Engine" – in itself also modular with regard to its functionality – serves from the viewpoint of the end user as "invisible" back end system. In general, the end users (elderly) are supposed to interact with the "engine" primarily in an indirect way through the Touchpoints.

Ethics Committee: According to Directive 2001/20/EC, is an independent body in a member state of the European Union, consisting of healthcare professionals and non-medical members, whose responsibility is to protect the rights, safety and wellbeing of human subjects involved in a clinical trial and to provide public assurance of that protection, by, among other things, expressing an opinion on the clinical trial protocol,

the suitability of the investigators involved in the trial and the adequacy of facilities, and on the methods and documents to be used to inform trial subjects and obtain their informed consent.

Integration activities: cover in REACH both the integration of parts and components to Touchpoints and the Engine (systems) as well as the integration of selected Touchpoints with each other and the Engine (to a system of systems) for certain verification/validation test scenarios.

Interface specifications: besides the system architecture, and the design of individual components or systems, interfaces play a key role in guaranteeing cross-compatibility.

Interfaces: A key aspect in that context is the identification and analysis of interfaces. Interfaces state ways of communication between system elements. According to Langford **(Langford, 2012**) in systems, individual elements can interact and interface in terms of four, basic ways: Energy, Matter, Material wealth and Information ("EMMI"). In **Deliverable D4** (**Section 5.5**) three types of interfaces have been identified a key for REACH: system-system interfaces, human-system interfaces, and B2B interfaces.

Machine Learning: Machine learning (ML) is the study of algorithms and mathematical models that computer systems use to progressively improve their performance on a specific task. Machine learning algorithms build a mathematical model of sample data, known as "training data", in order to make predictions or decisions without being explicitly programmed to perform the task.

MMAAT: Multimodal Multisensor Activity Annotation Tool which allows for intuitive labeling of the data providing multiple viewports for visualizing data.

Modularization: as defined for example by **(Baldwin & Clark, 2000**) can be considered as means to control the internal complexity of a system e.g. by reducing and clarifying the interfaces between system elements.

Performance specifications: e.g. specification of certain requirements the system must meet)

Sensing and data analytics process specifications: In REACH test with various types of sensors will be conducted in a variety of use case settings in different countries and under the control of different study leaders. In order to be able to exploit the resulting data sets efficiently by using data analytics algorithms, these data sets and the process of creating them must follow certain specifications.

Specifications: As per the NASA Systems Engineering Handbook (which principally follow the V-Model approach; see (**NASA, 2007**) throughout design and sub-system implementation phases progressively specifications and standards for the design/composition of individual system elements as well as the interfaces connecting them have to be identified and detailed in order allow a proper functioning of the system as a whole in verification and validation test phases.

System architecture specifications: High-level system architecture specifications were set up in **Deliverable T1.4/D4** (Chapter 5) clarifying the relations, interfaces, and the modular structure of the individual Touchpoints and their sub-systems and components with the Engine and the use cases to which.

System architecture: The structure of the overall system of systems is expressed by the REACH system architecture (following the terminology of the standard ISO/IEC/IEEE 42010:2011 **(International Standards Office, 2011**), see **Chapter 5/ Deliverable D4**) which decomposes the system, and defines links and information flows between the individual parts of the system and with the environment (stakeholders, use case settings, etc.).

Systems engineering: Langford (2012) characterizes systems engineering as the preparation of individual system elements for integration. System integration can efficiently be accomplished in a continuous, step by step manner (see, for example, the Continuous Integration Model as outlined by **(Northrop Grumman Corporation, 2011**) in which iteratively first selected components are integrated before subsequently larger sets of components are integrated in order to reduce the complexity of the integration process.

T: Task defined in the project proposal.

Technical specifications: detailed technical description of a system part of interface).

Technology validation: testing against system requirements

Technology verification: functional and usability testing

Touchpoints/Engine concept: structures the envisioned REACH product-service-system architecture, into manageable research and development clusters.

Touchpoints: The “Touchpoints” will act as “graspable” front end towards the end users (elderly). The Touchpoints will serve as data gathering devices as well as mediator of services and interventions coordinated by the Engine towards the end user. Each Touchpoint is modular and made up of several subsystems which allow to adapt the system both for a certain person or setting as well as over time.

TRLs, IRLs, SRLs: The concepts of Technology Readiness Levels (TRLs; see, for example, (**NASA, 2012**), and System and Integration Readiness Levels (SRLs/ IRLs, see, for example, (**Sauser, et al., 2006**)) can be used to track the maturity of the implemented sub-systems and their interfaces and integration with each other. In addition, project management can facilitate a successful system integration

Use case setting: Use case setting refers to the four solution operators and this report called them the use case setting since they reflect concrete application scenarios.

V-Model: REACH basically follows the so called “V-Model” (see for example (**Firesmith, 2013**)) approach which is of particular importance when developing solutions for the health care markets where the use of a systematic development method is pertinent also with respect to later certification requirements (**Harer, 2014**). Following the “V-Model” approach a design phase is followed by an implementation phase where fist individual systems/sub-systems-components are implemented, then subsequently and step wise integrated to systems for verification and validation.

WP: Work package defined in the project proposal.

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1 Background and introduction to task and activities related to T6.2/D26

WP6 targets implementation, integration, testing, evaluation and optimization of concepts and designs thus far developed in project REACH (a general overview of these concepts can be found in **Deliverables T1.3/D3 & T1.4/D4**). According to the proposed development approach, REACH project was divided into five Touchpoints and four use case settings. In this task/deliverable the conducted tests and trials in context of **TP1**, **TP2** and **TP3** will be presented. Furthermore, these trials were mainly implemented in two use case settings; for **TP1** and **TP3** at ZuidZorg use case setting and for **TP2** at TUM-br2 laboratory (since the Schoen-Klinik use case setting is a medical/clinical setting it requires proper ethics commission approval which requires timely application before running any trial involving patients. Consequently, it was decided to run an initial trial at TUM-br2 involving SK and FIAIS to prepare and submit a thorough ethics application. In the next phase, a trial will be executed at SK).

These trials aim to ensure that the designed systems/concepts adhere to regional standards. Implementing such trials will provide REACH partners with relevant information to recognize and prevent potential loopholes in a controlled care setting. Consequently, it will support future implementations in testing environments. Additionally, in such experimentations in a laboratory environment the real/final care setting can be simulated which will lead to finalized/optimized integration of platform system using the gained knowledge and experience.

The goals of this work task and deliverable report are;

1. to pre implement and pre integrate a mock-up of the previously introduced concepts

2. to detect, resolve and overcome the potential shortcomings and deficiencies in an early phase

3. to implement a pilot setup in a controlled care environment

4. to prepare and set an initial platform to collect data to prepare initial ground work for data analysis algorithms to be developed/refined

The chapters of this deliverable report cover the following thematic aspects:

- **Chapter 2 – Data Collection Workshop at TUM-br2 in Context of TP2:** This chapter provides details and presents a so called “Data Collection Workshop” at TUM-br2. This workshop is a pre-integration of a trial which will be held in a clinical/medical setting of SK. This workshop has 3 main targets namely, providing SK with enough information and details to prepare the ethics application, providing FIAIS with a rich data set so that they can start developing/adjusting machine learning algorithms, to run an initial trial by TUM including stationary/ambulant sensors (setting the ground work for future trial at SK).

- **Chapter 3 – Personalization Strategies Trial at ZuidZorg in Context of TP3:** This chapter provides details of testing toward understanding personalized motivational

strategies. This trial was implemented in a collaboration between TU/e, EPFL and ZZ. These trials aim to investigate personalize motivational strategies. In order to so, personal, psychological, contextual and behavioral factors were collected.

- **Chapter 4 – Trial at ZuidZorg in collaboration with Alreh Medical including the activLife in Context of TP1:** This chapter provides details on a concept solution which was developed to motivate the elderly to have a more active life style. This concept (personal mobility in TP1) includes an early detection factor and a case-oriented intervention factor. The early detection factor plays a crucial role in designing the solution due to the fact that this factor places a stepping stone for the intervention factor. Furthermore, it will provide a daily activity monitoring mechanism for the elderly.

- **Chapter 5 – Conclusion and Roadmap:** This chapter provides a summary of the results achieved in these trials. Additionally, an overview of the future steps will be provided.

In the following, an overview of **T6.2/WP6** of REACH is provided. This overview is presented in two sections. First, in **Section 1.1** the interdependencies of tasks in **WP6** is provided focusing on the role of **T6.2**. Secondly, in **Section 1.2** the relations of this task to other tasks of **WP1** and **WP7** are investigated.

1.1 Internal structure and planning of WP6

Considering **WP6** of REACH, the target of this Work Package is focused on systems engineering and testing. Such a target can be divided into system integration, verification, validation and optimization.

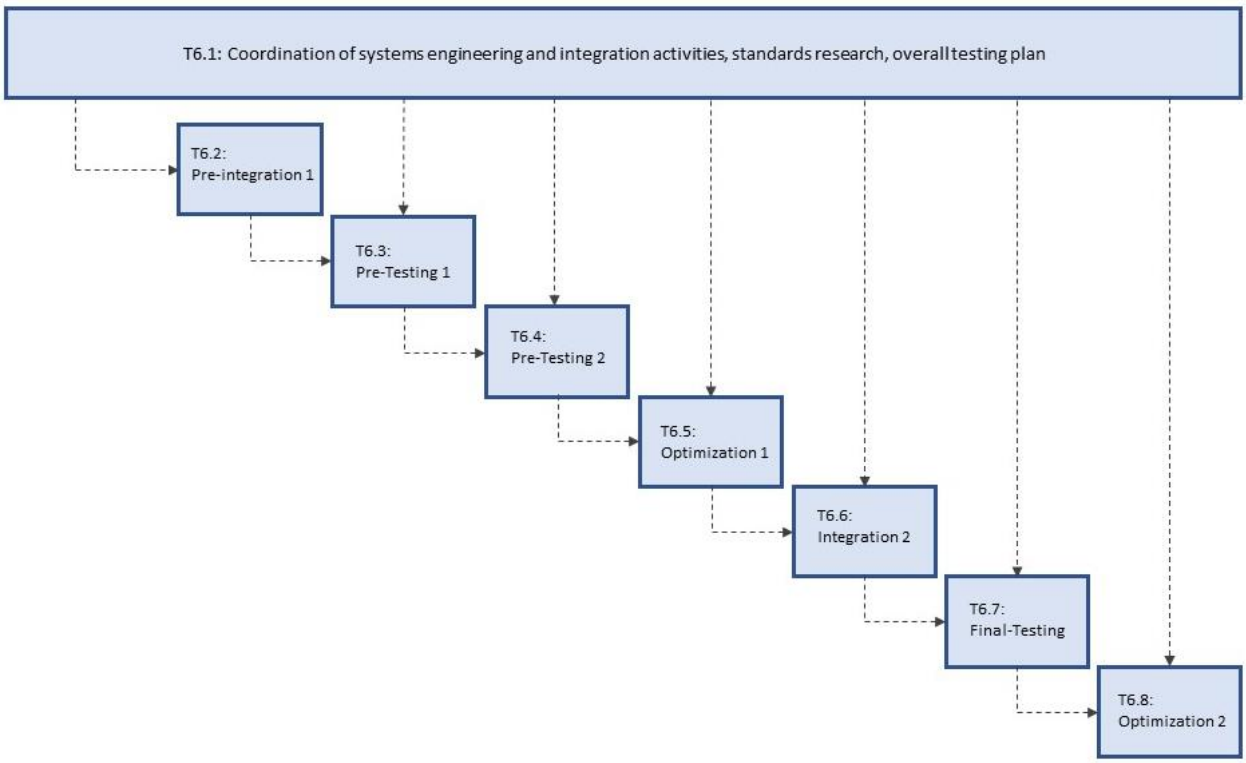

Figure 1-1: Relation of tasks within WP6 (Deliverable T6.1/D25)

Task **T6.1** focused on overall methods to provide a cross section between different work package tasks and best practices, standards, and coordination/planning of system integration activities. Furthermore, Task **T6.2** will implement the pre-integration phase which is the stepping stone for the rest of the tasks in this Work Package. This pre-integration will consider and include two major aspects. Firstly, considering the system integration and engineering and standard research concepts presented in **T6.1**. Secondly, the results and outcomes of the pre-integration will be used to improve the pre-testing phase in **T6.3**. Basically, this task will try to cover as much as possible the shortcomings and loopholes, so that very few problems occur during testing phase.

1.2 Relation WP1, WP7 and WP9

WP6 is closely linked to the system architecture (for example the Touchpoint/Engine concept) developed in **WP1** (presented in **Deliverable T1.4**/**D4**). Additionally, **WP1** provides the tools and methods to implement integration, verification, and validation. **WP6** presents and complements the actual implementation activities (individual technologies, components and sub-systems) conducted in smaller development sub-teams in the context of the **WP2** and **WP5**. From another perspective, **WP6** complements the **WP7** regarding the user acceptance and personalization strategies. This is due to the fact that all stages of integration and testing user acceptance, personalization and motivational strategies are considered and implemented. Furthermore, **WP6** aligns tightly with management activities of the **WP9**, since efficient communication and proper risk identification are crucial for system integration and implementation. Furthermore, “standards research” in **T9.4** focusses on the development of standards for the REACH external-environment and broader cross-compatibility and exploitation beyond the consortium and the project.

2 Data Collection Workshop at TUM-br2 in context of TP2

In this Section, integrations, implementations and trials executed for data collection at TUM-br2 in collaboration with SK and FIAIS is presented.

2.1 Planning, Integration and Execution

These set of trials executed in collaboration between TUM, SK and FIAIS cover **WP2**, **WP3** and **WP6**. These trials target to achieve the following goals

- Initial implementation, integration and functional test of the sensing systems
- Collecting initial data for testing the data annotation software
- Collecting initial data so that the development of machine learning algorithms can start
- Preparing data collection/acquisition protocols and defining detailed steps to be taken before running the data collection in a clinical environment
- In consideration of the generated data collection protocols and the sensing systems implemented, preparing the application for ethic commission with detail of technical setup which is close to a controlled clinical setting
- Defining and declaring a proper understanding of different terms between partners who have different background principles
- Based on the created understanding, proper task division between partners from different backgrounds
- Identifying loopholes and risks to improve efficiency for the clinical setup test
- A pre-integration was executed, to be prepared for the data collection in a clinical setup of the SK

In order to plan these trials (First one from 17 to 19 September 2018 and second one from 05 to 11 October 2018 at TUM-br2) several conference calls were hold starting from February-March 2018 once every few weeks. In the later phase, starting in August 2018, these conference calls were hold every week. These extensive conferences were hold in order to discuss, study and consider different aspects as well as to align and discuss implementation details and final integration. In the first data collection workshop at TUM-br2, the partners discussed the following in detail

- Introducing and collecting all different sensor and training how to properly collect data for data annotation purpose.
- The data format to be collected from different sensors was discussed.
- The data annotation software to be used (and the compatibility of collected data with the data annotation software). The two considered software were ELAN and MMAAT.

- The data collection/acquisition protocol (set of behavior and actions to be performed by the test person to collect data for drinking, eating, hygienic and activity).
- Discussing all the necessary technological implementation for data collection at SK.
- Installing all the sensors and running first trail runs.

The following figures present this workshop.

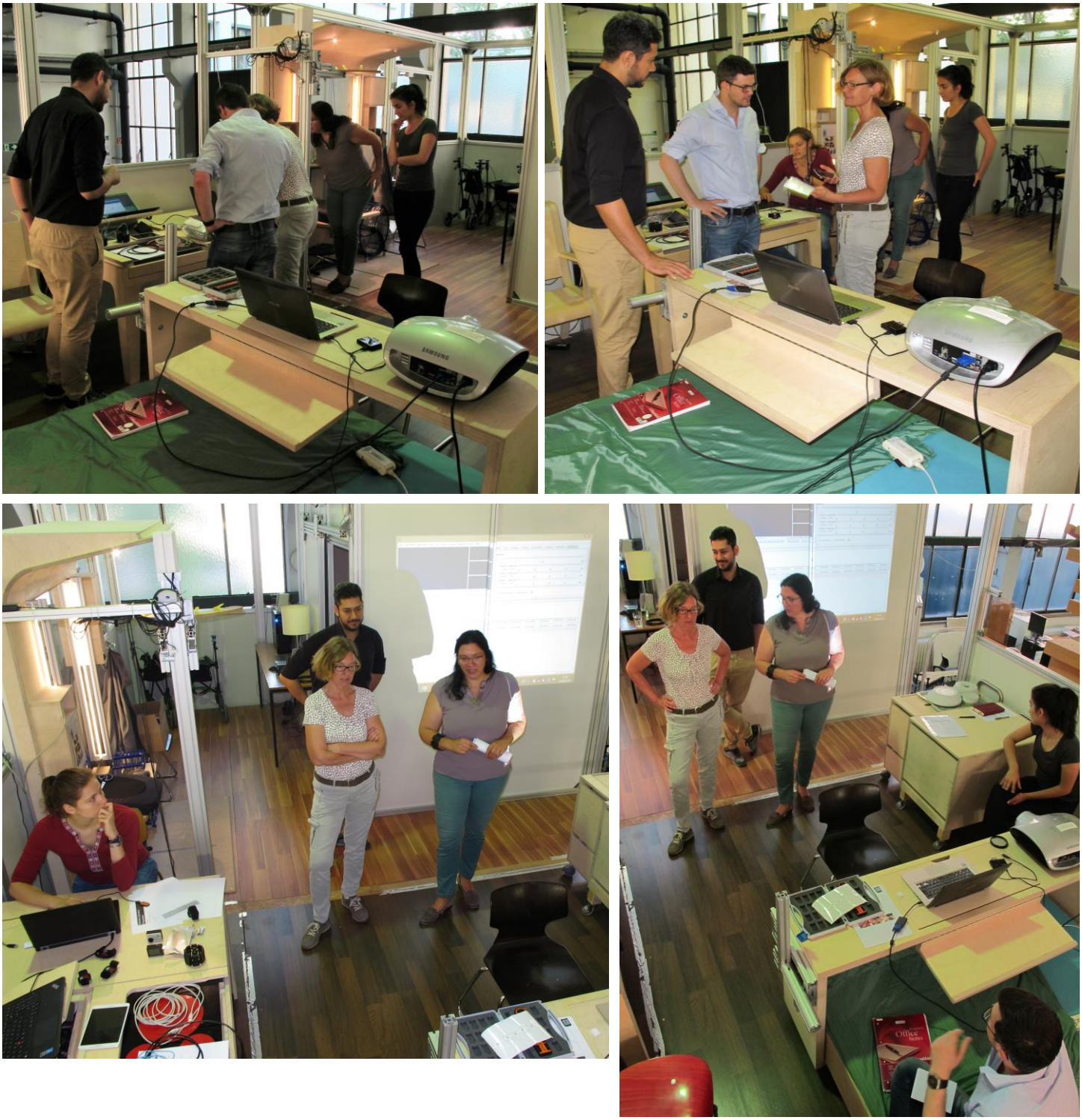

Figure 2-1: Preparation and alignment for the trial

Figure 2-2: Attaching sensors on the user and testing functionality

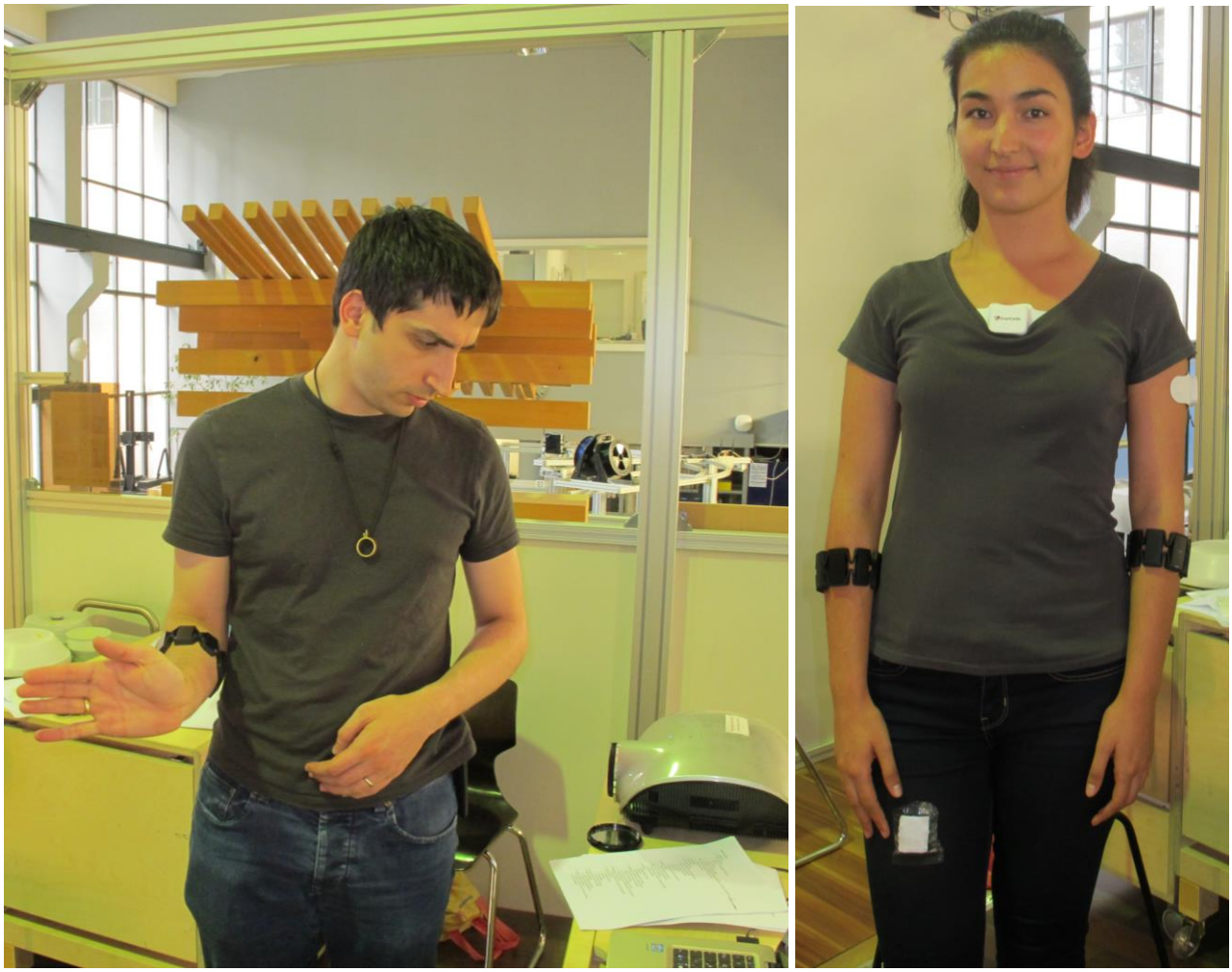

Figure 2-3: Attaching sensors on the user and testing functionality

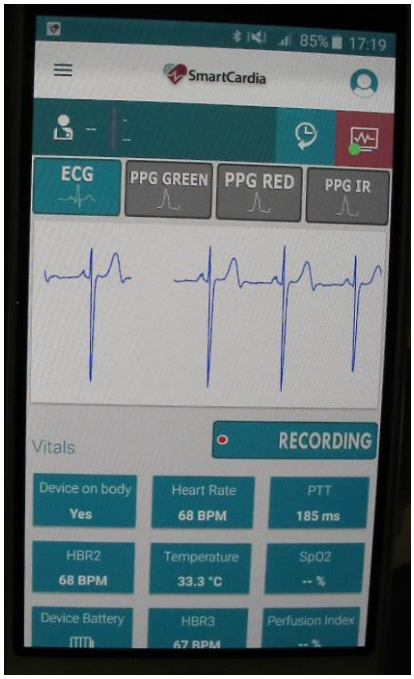

Figure 2-5: SmartCardia Sensor connected

Figure 2-4: ActivPal and sticker

Figure 2-6: Attaching the ActivPal sensors

Figure 2-7: running the test—Synchronization act and mattress data collection

Figure 2-8: running the test—Use of mobile phone and mattress data collection

Figure 2-9: running the test—Hygiene aspect, washing hands and brushing teeth

Figure 2-10: running the test—Hygiene aspect, brushing hair

Figure 2-11: running the test — writing and eating

Figure 2-12: Final synchronization act

In the second data collection workshop, firstly some test runs were executed to check the possibility for the data annotation and validation of the sensing system. Afterwards, using the available researchers from TUM, SK and FIAIS many Activities of Daily Living runs (ADL) and Drill Runs (DR) were executed and the data was properly collected and initially tested for future annotation.

The following sensors were integrated to execute this test

- SmartCardia Wearable Sensor (Accelerometer)
- Pressure Mattress (placed on the bed surface)
- Eight to nine ActivPal sensors (Accelerometer)
- Two MyoBand Sensors
- Five Cameras (Four fixed cameras and one mobile camera)
- Smartphone (Accelerometer and Gyroscope — Iphone)

The sensor placement and locations can be seen in figures below.

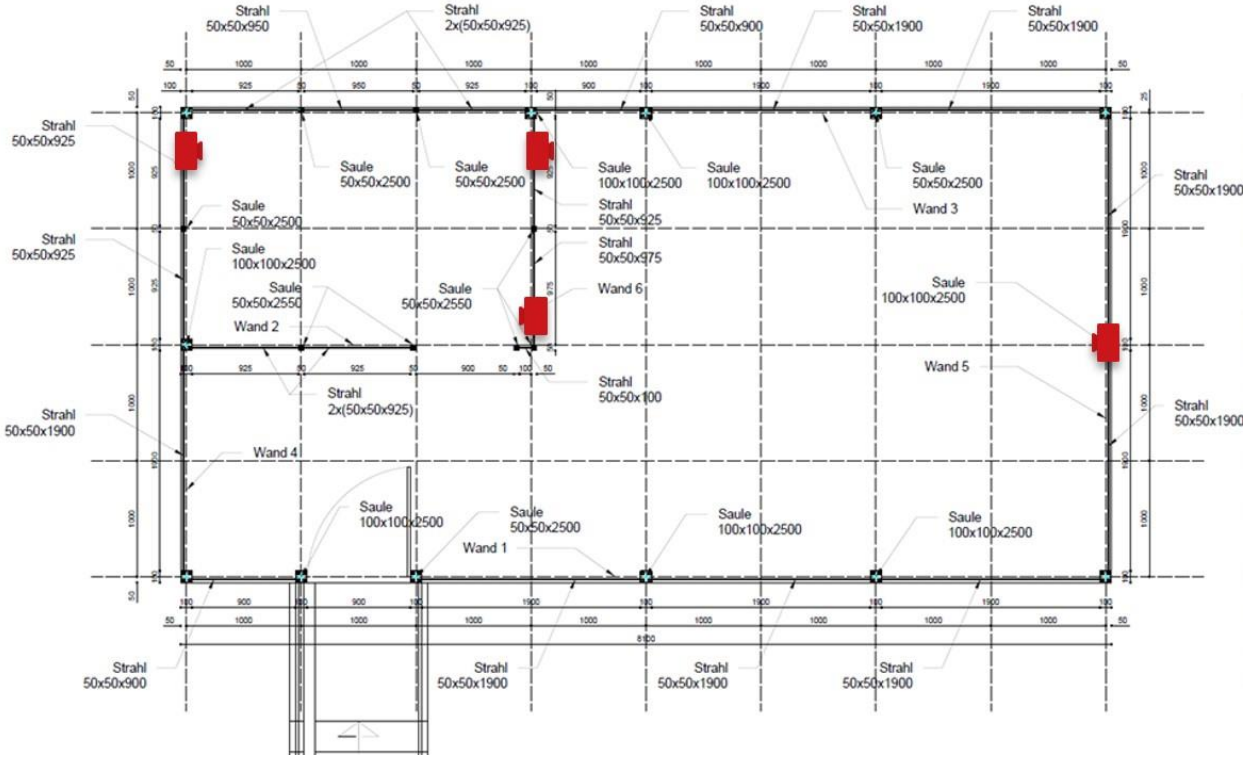

Figure 2-13: Mounting location of fixed cameras — Sketch overview of the test apartment at br2 lab

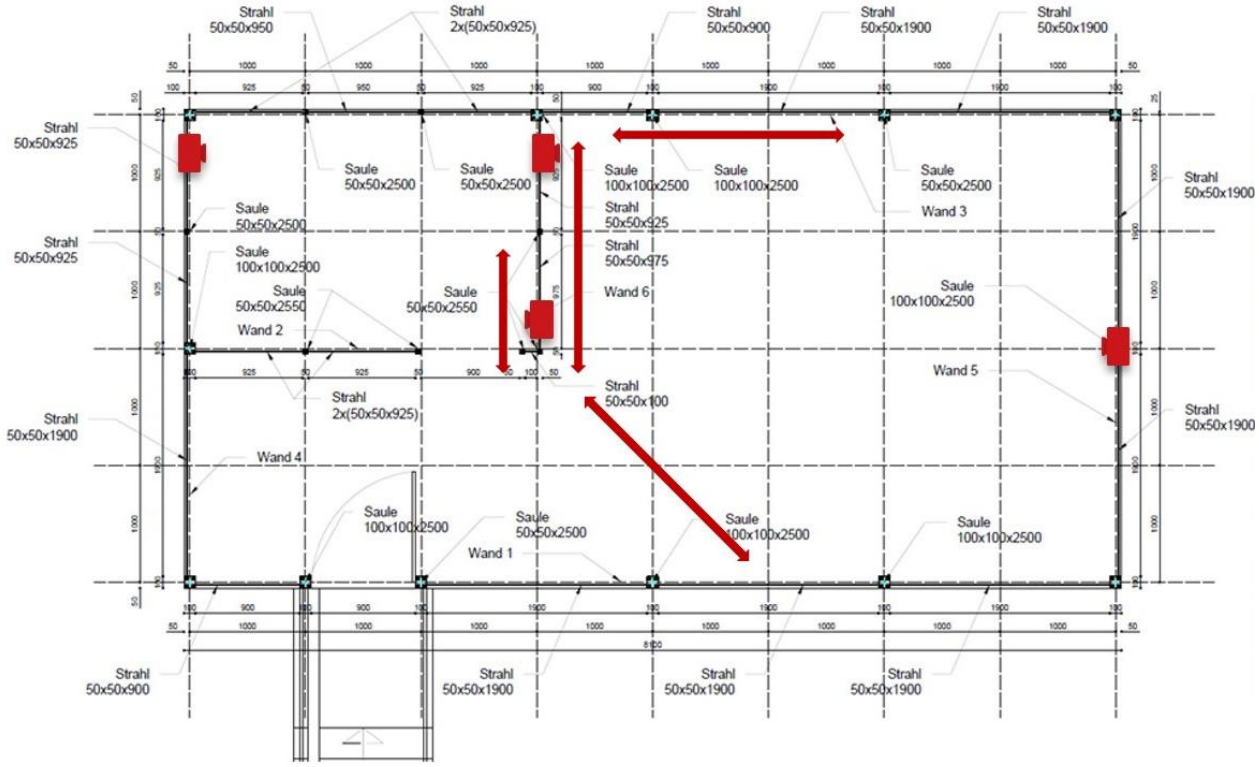

Figure 2-14: Moving directions of the mobile camera

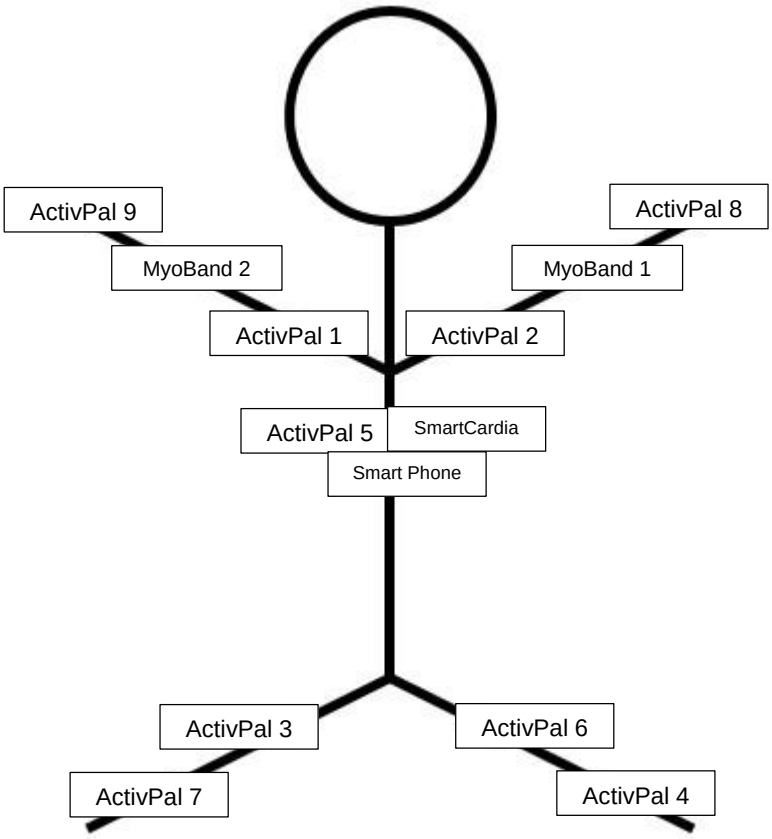

Figure 2-15: Wearable Sensor positioning on the test subject

The following images present the second data collection workshop including FIAIS, SK and TUM.

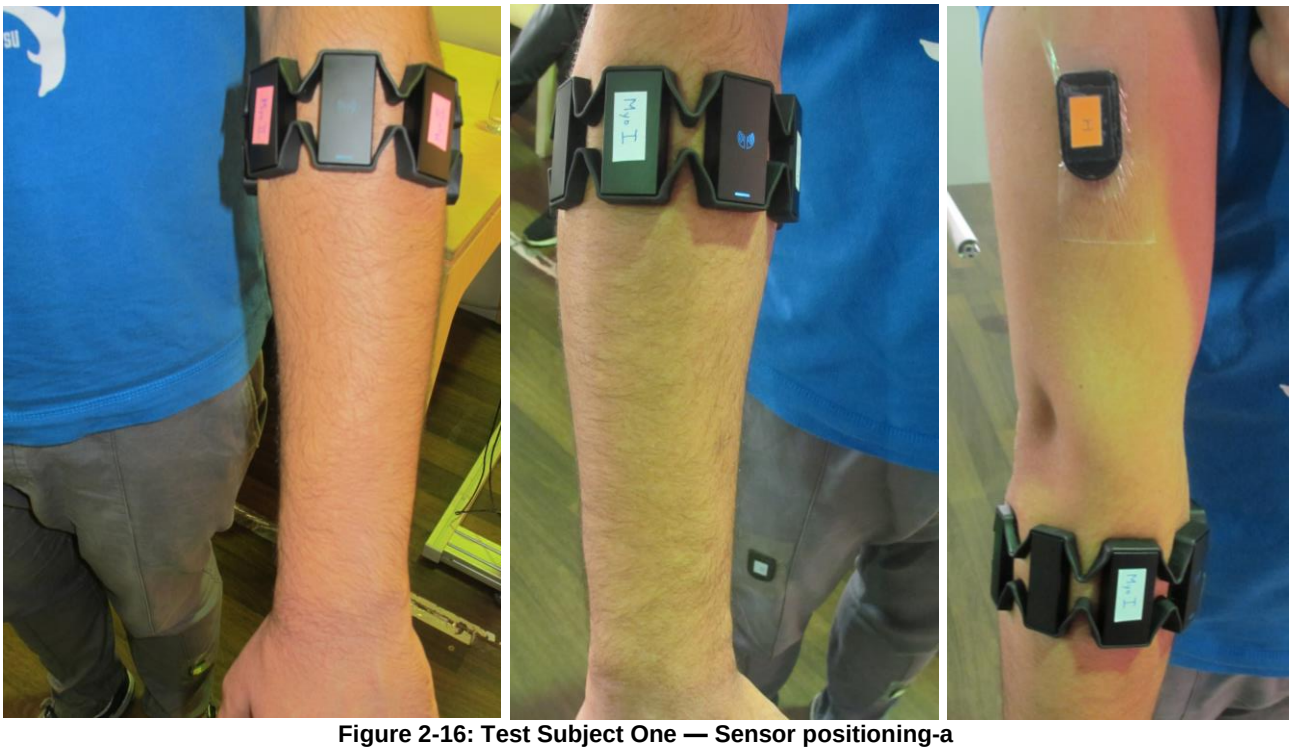

Figure 2-16: Test Subject One — Sensor positioning-a

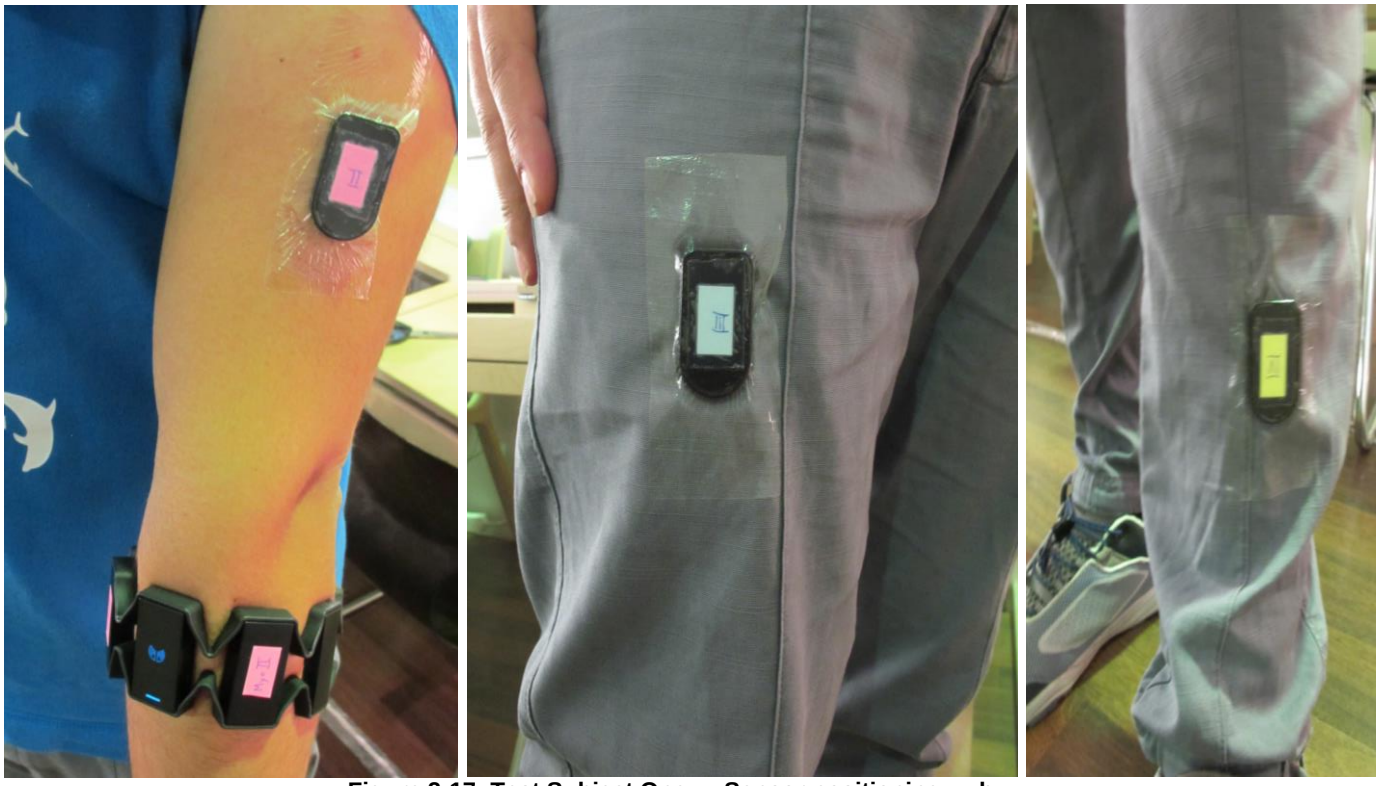

Figure 2-17: Test Subject One — Sensor positioning — b

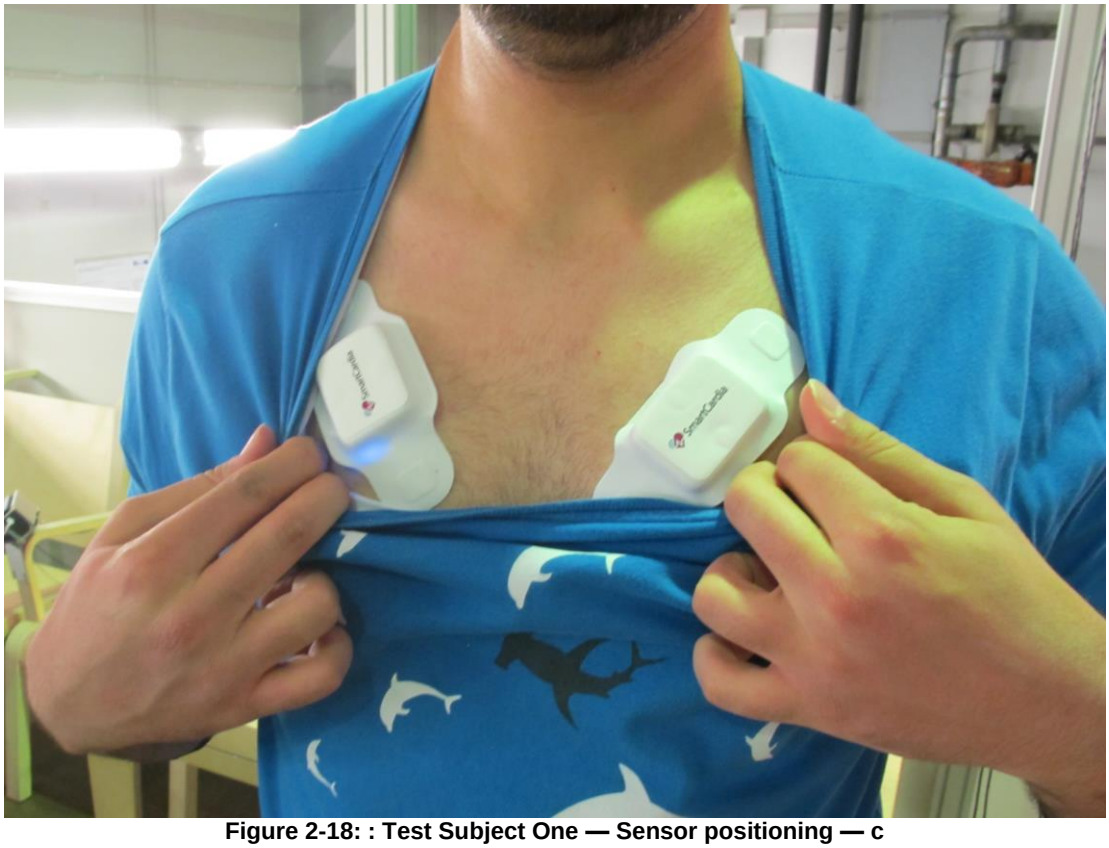

Figure 2-18: : Test Subject One — Sensor positioning — c

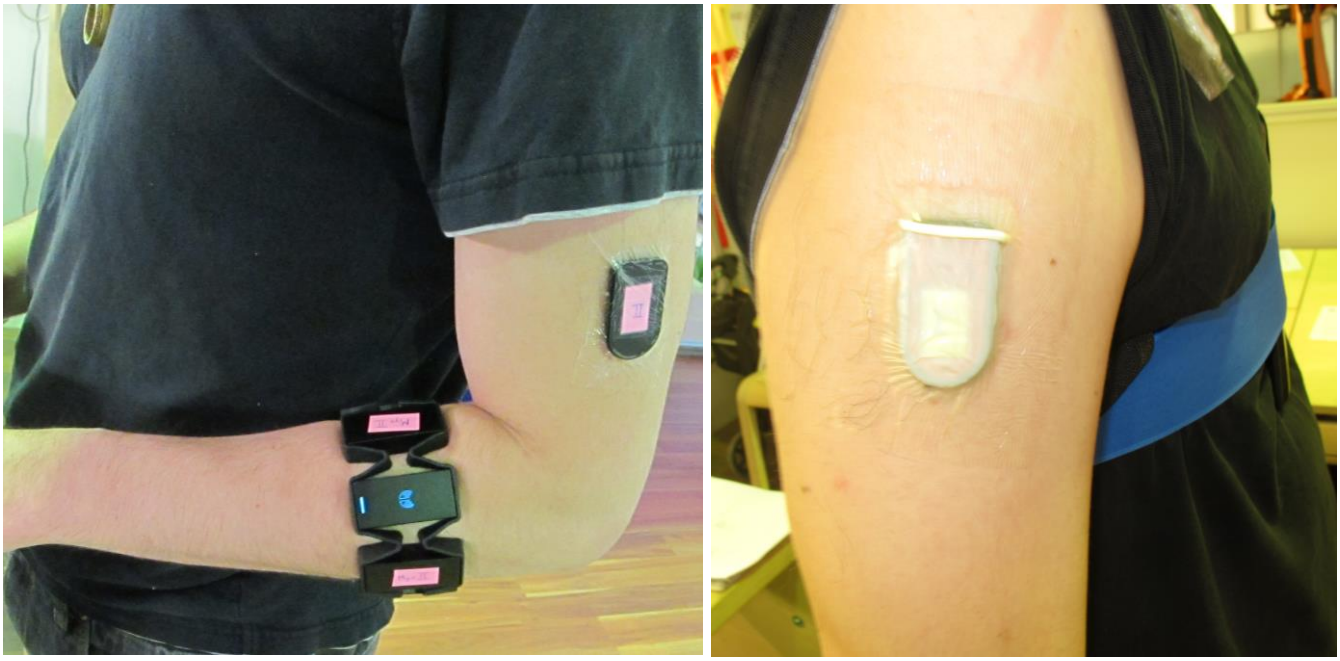

Figure 2-19: : Test Subject Two — Sensor positioning-a

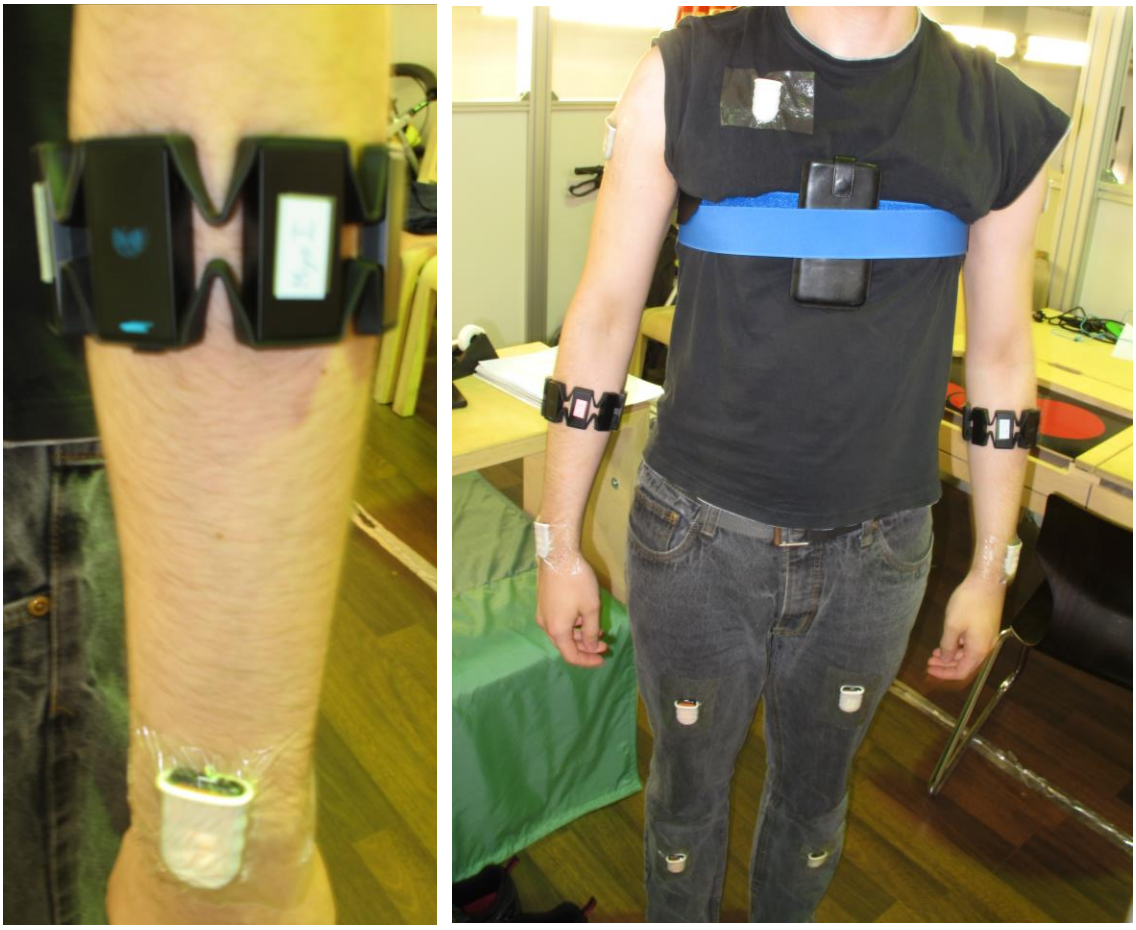

Figure 2-20: Test Subject Two — Sensor positioning-b

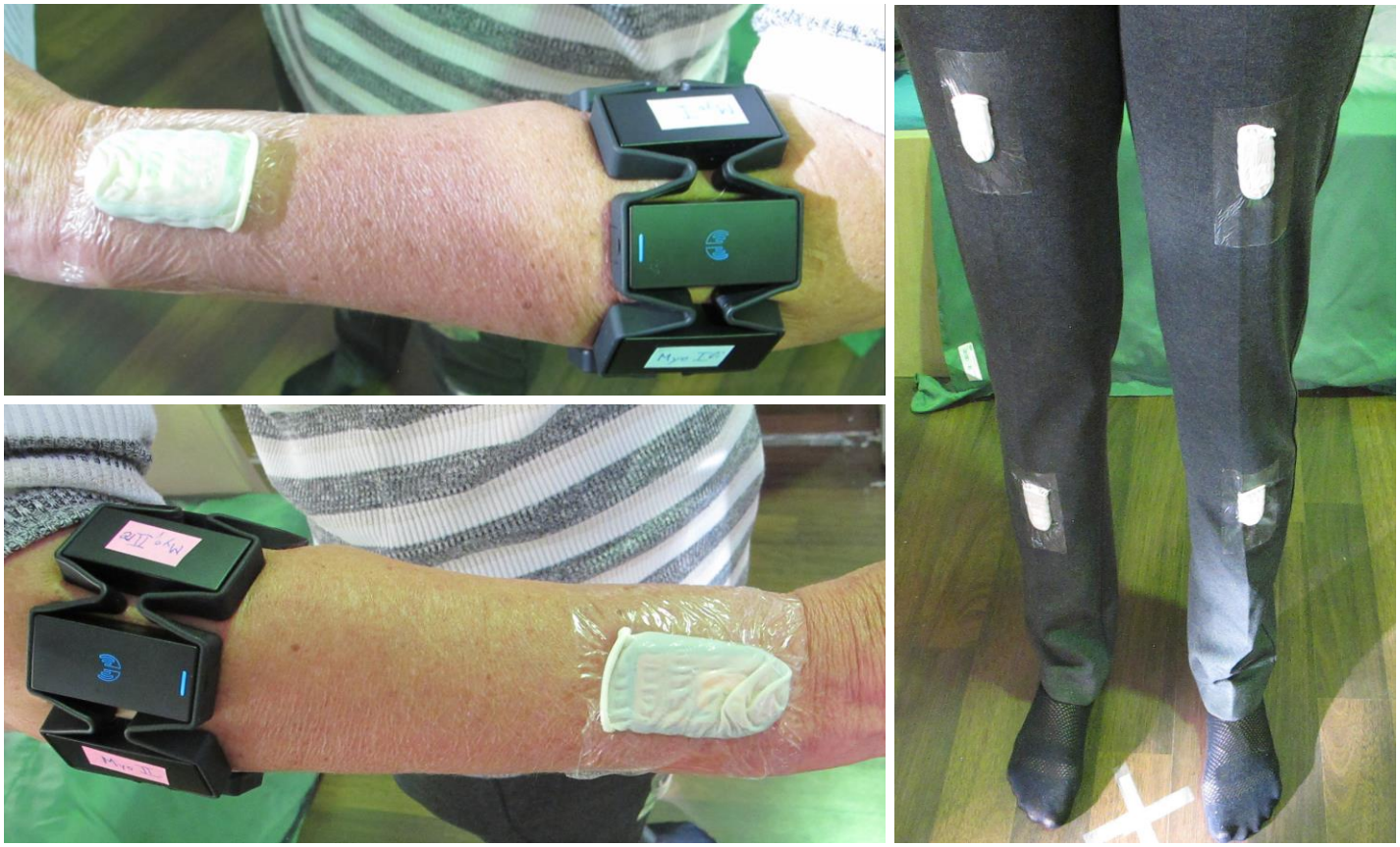

Figure 2-21: Test Subject Three — Sensor positioning-a

Figure 2-22: Test Subject Three — Starting the trial with positioned sensors

In addition to the presented images, there is a huge set of video footage taken from the ADL and DR tests including all four test subjects.

As a result of many phone conferences, it was agreed upon between SK, FIAIS and TUM to consider tracking of the following activities:

- Eating activities
- Drinking activities
- Hygienic aspect
- Motion and Locomotion
- Pill Intake
- Dressing Activities
- Activity level

In order to monitor the aforementioned activities a data acquisition protocol was developed. The data acquisition protocol is presented in **Appendix 2**.

In the next step, the collected data needs to be annotated in order to produce the classifiers for the machine learning algorithms. In order to implement this, two free software solutions were evaluated and considered, MMAAT (**DFKI, 2018**) and ELAN (**Institute, 2018**). In the first stage, it was cleared that the MMAAT software is lacking many aspects and needs further development to support the targeting task. On the other hand, the ELAN software proved effective and useful for our target. It is not covering the full set of requirements needed by FIAIS but it can support to a very good extent the required tasks. Consequently, it was decided to use this application for the data annotations. Furthermore, during the trials, applicability and usability of collected data for this application was tested and proved. An exemplary image of how the ELAN software interfaces the input data is presented in **Figure 2-23**.

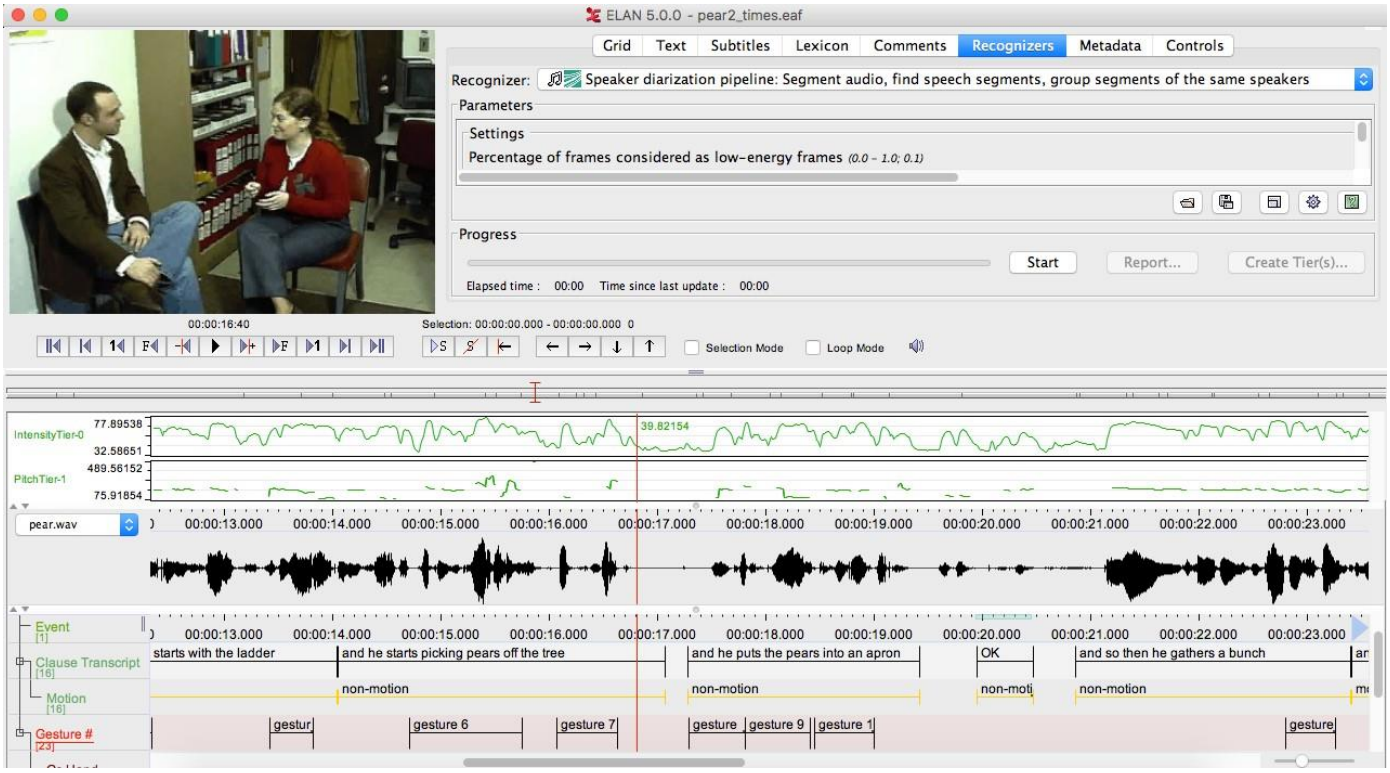

Figure 2-23: ELAN Software (Institute, 2018)

At the end it is worth mentioning that the EU General Data Protection Regulation (GDPR) (**EUGDPR, 2018**) is implemented and respected in all the data collection and processing stages of these trials. In order to properly address this issue, the data collection agreements were signed by all participants (data contributors) in these trials. An empty form of these data sharing declarations can be seen in **Appendix 1**.

2.2 Results of the workshop

The result of this workshop can be divided to three major aspects:

- **Data analysis aspect:** As a result of this workshop and in a close cooperation between SK, FIAIS and TUM, a large data set was recorded. This data set was initially examined to make sure that the data is properly collected and time stamped. Furthermore, the data was initially proved to assure possibility of annotating this data. After the data is annotated (marked) then the proper classifiers can be generated which will lead to developing proper machine learning algorithms. Consequently, this data set will provide FIAIS with enough information and a stepping stone to develop the machine learning (artificial intelligent) algorithms further ahead.

- **Clinical/Medical aspect:** As a result of this workshop and based on the collected experience, SK (the clinical/medical) partner can now prepare an ethics application to the authorities in Germany. After this application is approved by the ethics commission, the SK gets the permission to perform and implement a medical/clinical trial at their clinic. Basically, this trial is also setting the stepping stone for the SK to implement the trial.

- **Sensing and Monitoring aspect:** In the process of preparing for this workshop and as its result, a cross sectional (including ambient and wearable) sensing system was implemented at the br2 test apartment. This implementation sets the stepping stone for TUM in implementing the system at SK in 2019.

2.3 Addressed shortcomings/deficiencies & Next steps & Conclusion

There are some important issues to keep in mind regarding this test. The implementation and use of the cameras (4 fixed cameras mounted on the walls and 1 hand camera) is only for the purpose of data annotation and production of machine learning algorithms. This means the recorded video footage will be used by FIAIS to find a correlation between the action performed by the test subject and the signal pattern recorded by relevant sensors. Afterwards, these correlations will generate the classifiers required to develop and improve the machine learning algorithms. The video footage take by cameras are synchronized with a so called “Synchronization Action” performed by the test subject. The synchronization action is performed at the beginning and end of each ADL run and DR. Furthermore, it was considered to synchronize (as much as possible with “second precision”) the recording start of other sensors such as SmartCardia sensor, Pressure mattress sensor, Myoband sensors, ActivPal sensors and Mobile phone. In order to find a proper implementation approach for the sensors to synchronize, the team needed a few test runs to find out all the loopholes and shortcomings.

As the next step, the data annotation will start as soon as possible to go through the data and find proper data patterns and define classifiers. Furthermore, it should be considered that the collected data set is not the final data, this data was collected only to be a stepping stone for developing the algorithms. The final data which will be kept on the REACH Engine will be collected during future trials at SK (or other partners site where elderly citizens are available for testing) and with real patients/elderly citizens. After the trial at site of SK or other partners, the machine learning algorithms can be further refined and detailed. Finally, in the trial executed at TUM-br2, we used many sensors of the same type. In the final trials and after the algorithms are running with an acceptable performance, we can remove the redundant sensors to improve user acceptance and convenience.

3 Personalization Strategies Trial at ZuidZorg in Context of TP3—A collaboration between TU/e, EPFL and ZZ

In this section, continued testing toward understanding personalized motivational strategies is described.

3.1 Planning, Integration and Execution

The purpose of the continued test was to investigate how to personalize motivational strategies. In order to investigate personalization, personal, psychological, contextual and behavioral factors were collected. In addition, it was observed to what extent people changed their behavior when exposed to different motivational strategies. research will then explore how personal motivational profiles can be created from analyzing which personal factors are predicative of to what extent people changed their behavior in response to certain motivational strategies.

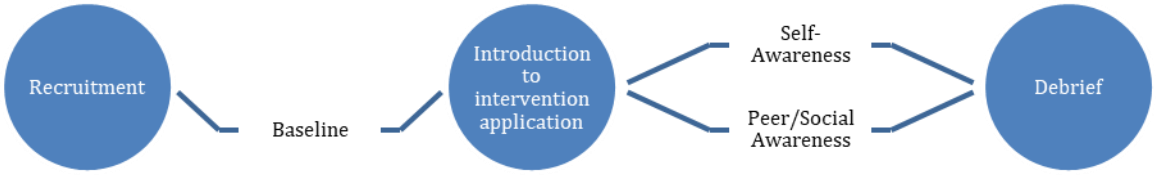

Figure 3-1: Continued Testing Protocol

To investigate how to personalize motivational strategies a random control trial was done including 61 people recruited from the local community dwelling member of ZuidZorg extra, a senior community center in Eindhoven the Netherlands. Figure 1 summarizes continued testing protocol. After recruitment, participants were introduced to provided technology which will be used in this case. Hardware included the Fitbit Flex 2, an activity tracker and the Mi A1 smart phone. During the four-week baseline participants got used to using and maintaining the new technologies. Participants had access to a technical support hotline 7 days a week via phone and email. During these first four baseline weeks no motivational strategies were implemented. After this baseline, researchers led a workshop building on their current interaction with the new technologies to introduce participants to the intervention application. The intervention application was presented in one of two forms, so that roughly half of the participants used an application based on the motivational strategy self-awareness and the other half used the application based on social-awareness, see **Figure 3-1**.

3.1.1 Data collection

Continued testing here relies on data collection both qualitative and quantitative. **Table 3-1** describes the nature of the data collected and **Table 3-2** describes the data collection process.

Periodic measurement (profiling questionnaire)			Continuous measurement (data collected through application)	
Psychological Profile	**Contextual Profile**	**Reported Behavioral Profile**	**Measured Behavioral Profile**	**Measured Intervention Interaction**
Stage of Change	Age	Past physical activity engagement	Step data	Number of messages sent through the application
Self-efficacy	Gender	Current physical activity level		Kinds of messages send (whether cheer or taunt)
Social self-efficacy	Living situation			
	Level of intimacy with team			
	Smart phone experience			

Table 3-1: Data Collection

Data	Baseline (4 weeks)	Intervention with modified Healthy Together application (5 weeks)
Psychological Profile	×	×
Demographic Profile	×	
Reported behavior Profile	×	×
Measured behavior Profile	×	×
Measured Intervention Interaction		×

Table 3-2: Data Collection Process

3.1.2 Intervention application design

The intervention application used was adapted from the HealthyTogether application, originally created for a test involving university students, see **Figure 3-2** .

Figure 1. HealthyTogether main interfaces and Fitbit tracker interfaces: a) Fitbit displaying step count, b) HealthyTogether step interface, c) HealthyTogether floor interface, d) Fitbit displaying floor count.

Figure 3-2: Original design of the HealthyTogether Application (Chen, Yu and Pu, Pearl, 2014)

To make this interface usable for the user group of older adults, the application was redesigned through a co-design process with a focus group from the recruited participants. Figure 3-3 depicts the resulting application.

Figure 3-3: A representation of the co-design sessions

Figure 3-4: Re-designed HealthyTogether application

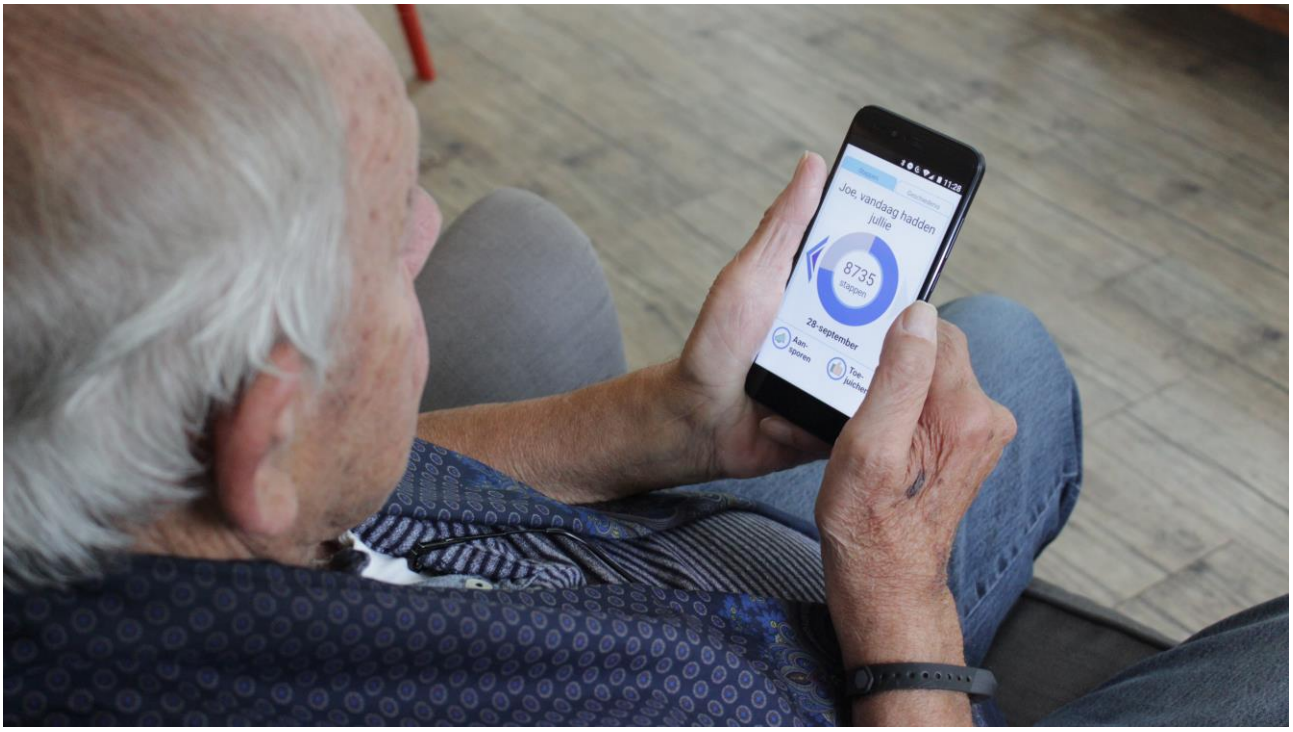

Figure 3-5: Participant of the test using the re-designed HealthyTogether application

3.2 Results of the Trial

Though the analysis of this research is still ongoing we have already found several important topics to be aware of, which needed to be addressed to reach investigation objectives. Important challenges to be addressed were recruitment of participants, high dropout rates, limited technology acceptance among participants and issues related to data collection resulting in missing data.

To address these challenges, we created a product service system to enable the necessary in-context research with older adult participants. **Figure 3-6** illustrates the product service system approach to in-context research we used to address the identified challenges.

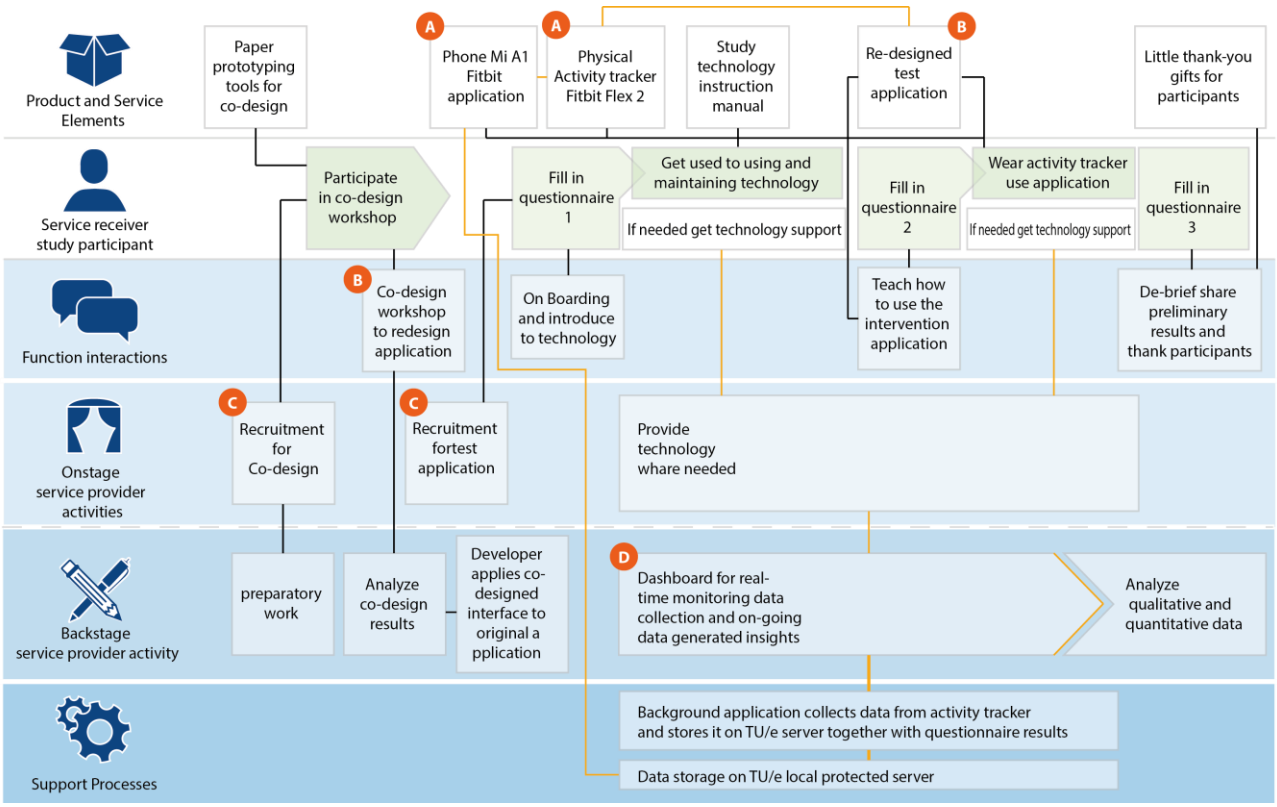

Figure 3-6: Product service system used to address challenges we faced with this in-context study on personalizing behavior change strategies

3.3 Addressed shortcomings/deficiencies & Next steps & Conclusion

Lack of technology acceptance and limited experience with technology can often pose challenges for researchers to engage older adults to engage in research studies, exploring new technologies (**Chen & Chan, 2011**) (**Mitzner, et al., 2010**) (**Valenzuela, et al., 2018**) (**Kopeć, et al., 2018**) (**Eisma, et al., 2004**). To address the limited experience with technology, which many participants self-reported in questionnaires, the research team took considerable care to choose the products used in this investigation, see items in **Figure 3-6** marked "A". The Mi A1 phones has a large screen and provides many options to improve the legibility such as increasing text and icon sizes. The options were all pre-set by members of the research team in preparation for the investigation. The Fitbit Flex2 is a simple activity tracker, which would hardly take away from the tested interventions. It does not have a screen so participants for participants to check their step count throughout the baseline of the test or without interacting with the test intervention application. Furthermore, the original Healthy together application was re-designed through a co-design process to support this applications usability for the participants of this study, see B in **Figure 3-6**. Being aware of the specific needs of the test population allowed researchers to appropriately address the challenges cause by limited experience with technology, by carefully choosing and preparing the intervention tech ology.

Recruitment of older people to participate in a research study involving technology is also often cited as a challenge by experienced authors (**Binda, et al., 2018**) (**Holroyd-Leduc, et al., 2016)** (**Provencher, et al., 2013**). For this investigation researchers teamed up with familiar and trusted persons from the senior citizen community center, to recruited members interested in participating the continued testing, see C on **Figure 3-6**. Through this approach to recruitment, researchers believe many more people were enthusiastic to join the study.

In addition, the recruitment and the various workshops were done at the familiar location of the senior community center, which senior community center representatives reported would not only be logistically more attractive to participants but also make them feel more comfortable to join the research study.

In previous early testing, researchers found that participant engagement was important to avoid participant dropout. In early testing it was observed that participants were very disappointed when data collection would not work, as many participants cited gaining information on their physical activity to be a key reason to participate in the study. Also, it was observed that participants who realized their data had been lost worried about whether their participation was still contributing to the research. In early testing data loss and data inconsistencies were caused by the instability of test prototypes and because participants interact differently than the test protocol anticipates.

To support participants in their use of the newly offered technologies researchers offered a seven day a week support line which they could reach via email, WhatsApp or phone call (of which phone call was far the most used avenue for communication). Study participants were encouraged to call the reach out to researcher when they needed help or had any questions about the devices used in the study. Researchers in this study believe that this support served to keep participants engaged when faced with difficulties, possibly accounting for the relatively low dropout rate. During this continued testing investigation, a dashboard allowed researchers to monitor incoming participant data I real time, see D in **Figure 3-6**. I this way researchers were aware of gaps in participant's data as it occurred and were able to call participants to trouble shoot and solve the issue to ensure stable data collection again. This was important because participants did not always notice that something was not working as it should be, or they forgot to charge the devices. Other times they mentioned they had noticed that something might not be working as it should but they did not want to "bother" the research team, so were happy and relieved when the research team reached out to them instead. Through these measures of real time data monitoring and on-demand technology support, researchers addressed the challenges posed by high dropout rates and incomplete data sets.

Figure 3-7: impression of the dashboard for real time data monitoring, questionnaires to be digitized and the paper manuals for participants to support their use of the provided technologies

4 Trial at ZZ in collaboration with Alreh Medical including the activLife in Context of TP1

In TouchPoint1 of the Reach Project, we have developed a concept solution to motivate elderly citizens to be more active in everyday life. The concept of personal mobility in TP1 should contain an early detection process and a case-oriented intervention process. The early detection process is a very important element in designing the solution, which will monitor the daily activities of the elderly and respond accordingly in the event of a fall. Due to early detection of changes at the level of daily activity, an individual intervention program can be implemented to protect the elderly against progressive inactivity and to allow them to stay at home for as long as possible which will protect them from unwanted hospitalization. In order to safely increase the daily activities among the elderly, the activLife concept was designed and developed by Alreh Medical. **Figure 4-1** presents this concept.

Figure 4-1: ActivLife-multifunctional interactive activation device by Alreh Medical

In order to implement the designed concept, a trial was conducted in a collaboration between ZuidZorg, TU/e and Alreh Medical at the Meet and Greet center of ZuidZorg in Eindhoven. The activLife device was pre-tested from October to November by providing users with a questionnaire. This questionnaire targeted mainly the accessibility of the device. During this period, the sports coach was present to support the users with filling in the questionnaire. For the first phase 14 participants who took part in ZuidZorg Meet and Greet vitality square were involved.

The main testing phase lasts 3 months (from December to march 2018). During this phase, the participants follow a personalized ActivLife program. This program will initially be under the guidance of a sport coach later they can use the equipment individually (personalized programs) unattended. The interface and the use of the activLife device was adapted to the participants' individual exercise.

Through the testing phase several aspects were measured:

1. Mobee fit test baseline measurement survey done on single physical move points of the participants. (neck, shoulder and hip mobility).
2. Increase of motivation to be more active by the use of activLife among the participants- User motivation & Acceptance questionnaires (Barriers to be active quiz)
3. Tinetti Balance test
4. 4 stages Balance test
5. The 30 seconds Chair Stand Test (**Figure 4-2**)
6. Dynamometer strength measurement of a hand grip
7. Research questionnaire

Figure 4-2: The 30 seconds chair stand test

4.1 Planning, Integration and Execution

The target user group for the testing were Seniors who live independently at home and are willing to be more physically active, however are not yet motivated to do physical activities on regular basis

Test Protocol:

Group A **Intervention 1 with activLife (8 weeks)**

These participants were using the activLife equipment for 8 weeks, guided and supported by a sport coach. The training was performed twice a week for 30 minutes every session. Each participant received a test map which consisted of:

- Introduction and explanation of the exercises and questionnaires
- Training program, schedule for 8 weeks. With a personalizes time program for each participant for the support of the sport coach
- Questionnaires

Figure 4-3: activLife Training Session

Before starting the first exercise

- Stage of change
- Barriers to being active
- Tilburg Frailty Indicator

After each exercise

- RPE scale
  Once a week during the 8 weeks

- Intrinsic motivation scale

Group A	Tasks	Baseline 8 weeks	Intervention 1 with activLife (8weeks)	Post study
	Age, gender, BMI, TFI	×		
	Stage of change questionnaire	×		×
	Tilburg Frailty Indicator	×		
	Strength test	×		×
	Mobee Fitness measurement	×		×
	Barriers to Being Active Quiz	×		×
	Self reporting exercise		×	
	Rating of perceived Exertion (weekly after each exercise)		×	
	Intrinsic Motivation Inventory (once, weekly)		×	

Table 4-1: Group A study protocol

Group B

These participants were doing several exercises with written instruction and advices from physiotherapist.

Each participant received a test map consisting:

- Introduction and explanation of the exercises and questionnaires
- Exercises to perform at home to improve mobility of the neck-shoulder-back
- Questionnaires:

Before starting the first exercise

- Stage of change
- Barriers to being active

- Tilburg Frailty Indicator

After each exercise

- RPE scale

Once a week during the 8 weeks

- Intrinsic motivation scale

Figure 4-4: Participants completing questionnaires

Group B	Tasks	Baseline 8 weeks	Intervention with assignment from Physiotherapists at home (8 weeks)	Post study
	Age, gender, BMI, TFI	×		
	Stage of change questionnaire	×		×
	Tilburg Frailty Indicator	×		
	Strength test	×		×
	Mobee Fitness measurement	×		×
	Barriers to Being Active Quiz	×		×
	Self- reporting exercise		×	
	Rating of perceived Exertion (weekly after each exercise)		×	
	Intrinsic Motivation Inventory (once, weekly)		×	

Table 4-2: Group B study protocol

Objectives of the study:

- Investigate whether the motivation to do more physical activity is the same for seniors who use activLife and for those who follows the advices from the physiotherapists at home.
- Show an improvement in certain clinical "outcomes" such as physical strength, balance, and risk of falls after the use of mobility activLife and after following standard physiotherapist recommendation at home.
- Determine whether the seniors remain in the same stage of change when they use activLife equipment and when they follow the advices from the physiotherapist at home.

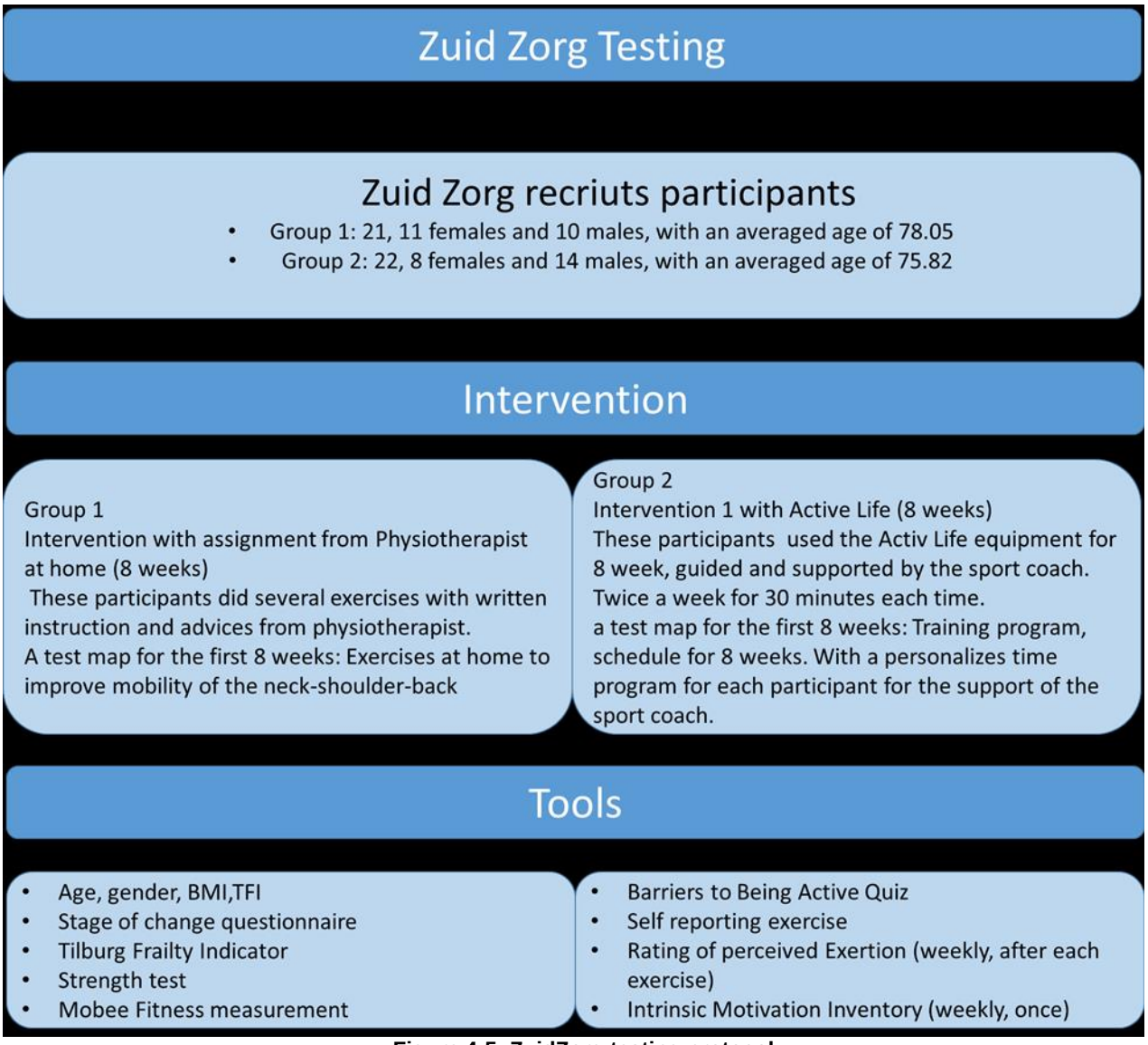

Figure 4-5: ZuidZorg testing protocol

4.2 Results of the Trial

Test Participants:

- Group 1: 21, 11 females and 10 males, with an average age of 78.05
- Group 2: 22, 8 females and 14 males, with an average age of 75.82

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	3.944	.260	3.417	4.472
	2	3.944	.337	3.261	4.627
B	1	4.550	.247	4.049	5.051
	2	3.850	.319	3.202	4.498

Figure 4-6: The Stage of Change questionnaire, Stage 1=2

The stage of change questionnaire results of the baseline stage and intervention stage showed no statistically significant change for both groups.
The stage of change results of Group A with the activLife intervention were not statistically significantly different than those of Group B with the physiotherapist's intervention (**Figure 4-6**).

1. Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	8.639	.296	8.038	9.240
	2	9.028	.311	8.397	9.658
B	1	9.513	.281	8.943	10.082
	2	9.538	.295	8.939	10.136

Figure 4-7: 4 Stage balance test, Stage 1=2

The 4 stage balance test results do not differ significantly at the baseline and intervention stage for both groups.
The test results of Group A with activLife intervention are statistically higher than those of Group B with the physiotherapist intervention. This result implies that training with activLife improves the 4-stage balance of the target user group (**Figure 4-7**).

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	9.882	1.114	7.622	12.143
	2	12.353	1.241	9.834	14.872
B	1	12.000	1.027	9.916	14.084
	2	13.300	1.144	10.978	15.622

Figure 4-8: 30 seconds chair stand test results

The amounts of 30 seconds chair stand performed is statistically higher at the intervention stage than the baseline stage for both groups (**Figure 4-8**).

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	9.882	1.114	7.622	12.143
	2	12.353	1.241	9.834	14.872
B	1	12.000	1.027	9.916	14.084
	2	13.300	1.144	10.978	15.622

Figure 4-9: 30 seconds chair stand test results

The amounts of 30 sec chair stand performed by group A with activLife intervention statistically do not differ significantly compared to those by group B (**Figure 4-9**).

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	.778	.793	-.831	2.387
	2	2.444	1.028	.360	4.529
B	1	1.600	.753	.073	3.127
	2	3.000	.975	1.023	4.977

Figure 4-10: 30 second chair stand, scores Group A = B

The scores of the 30 chair stand test of the group with the activLife intervention statistically does not differ significantly from those of the group with physiotherapist (**Figure 4-10**).

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	3.333	.653	2.009	4.657
	2	3.056	.658	1.721	4.390
B	1	3.300	.619	2.044	4.556
	2	2.900	.624	1.634	4.166

Figure 4-11: TFI stage 1=2

The Tilburg Frailty Index at the baseline do not differ statistically significantly from those at the intervention stage for both groups (**Figure 4-11**).

Group * stage

Measure: MEASURE_1

Group	stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	3.333	.653	2.009	4.657
	2	3.056	.658	1.721	4.390
B	1	3.300	.619	2.044	4.556
	2	2.900	.624	1.634	4.166

Figure 4-12: TFI measurement

The Tilburg Index of the group with activLife intervention do not differ statistically significantly from those of the group with the physiotherapist intervention (**Figure 4-12**).

Group * Stage

Measure: MEASURE_1

Group	Stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	1.746	.269	1.200	2.292
	2	1.746	.259	1.221	2.271
B	1	.564	.255	.047	1.082
	2	1.271	.246	.773	1.770

Figure 4-13: Barriers to be active quiz results

The “Barriers to be active quiz” results are statistically lower at the baseline stage compared to those at the intervention stage (**Figure 4-13**).

Group * Stage

Measure: MEASURE_1

Group	Stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	1.746	.269	1.200	2.292
	2	1.746	.259	1.221	2.271
B	1	.564	.255	.047	1.082
	2	1.271	.246	.773	1.770

Figure 4-14: Barriers to be active quiz results, Group A > B, p < .05

ActivLife users seem to have a clear barrier to be active, possibly due to technology involved; Group B (home) has higher barrier to be active scores after intervention than at the baseline; however, group A (activLife) keeps the same level (**Figure 4-14**).

Group * Stage

Measure: MEASURE_1

Group	Stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	56.121	5.076	45.826	66.415
	2	53.132	5.471	42.037	64.227
B	1	63.142	4.816	53.375	72.908
	2	63.324	5.190	52.798	73.850

Figure 4-15: Hand grips strength measurement

The hand grips test results at the baseline stage do not differ statistically significantly from those at the intervention stage for both groups. The hand grips test results of the group with activLife intervention do not differ statistically significantly compared to those of the group with physiotherapist intervention (**Figure 4-15**).

Group * Stage

Measure: MEASURE_1

Group	Stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	91.535	2.527	86.409	96.660
	2	94.556	2.131	90.235	98.877
B	1	93.294	2.397	88.431	98.156
	2	94.594	2.021	90.494	98.693

Figure 4-16: Mobee range of motion measurement

The Mobee test results of the group with activLife intervention do not differ statistically significantly compared to those of the group with physiotherapist intervention (**Figure 4-16**).

Group * Stage

Measure: MEASURE_1

Group	Stage	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
A	1	24.238	.692	22.839	25.638
	2	22.190	1.791	18.570	25.811
B	1	26.048	.692	24.648	27.447
	2	25.857	1.791	22.236	29.478

Figure 4-17: Tinetti Balance Test results

The Tinetti Balance test results at the baseline stage do not differ statistically significantly from those at the intervention stage for both groups. Tinetti Balance, Group B > A, $p < .10$
The Tinetti balance test results of the group with activLife intervention is statistically significantly lower compared to those of the group with physiotherapist intervention (**Figure 4-17**).

4.3 Addressed shortcomings/deficiencies & Next steps & Conclusion

The test participants were from a physically active group with comparable TFI, stage of change measurement and hand grip test results (which is the sign of frailty).
The activLife training improves the 4-stage balance test and 30sec chair stand test results. Exercises provided in the training program gave the participants opportunity to practice sit-ups and balance in a safe standing position. As there is no walking exercise in the activLife training program it does not sufficiently improve the Tinnetti Gait Assessment results.
The study results showed a huge role of a sport coach in engagement process of the elderly to motivate more physical activity. Exercise alone at home has a higher barrier to be active score than exercise together with a sport coach support.

Figure 4-18: ActivLife training program

Based on the knowledge and experience gained during the testing study in ZuidZorg, it can be conclude that Intervention should start by individual involvement of a “sport coach” and develop toward new social and trainig habits. Activity Centers such as ZuidZorg provide a great potential to be an “early detection center” for monitoring the level of activity among the elderly. An individual intervention program should be implemented quick enough to protect the elderly against progressive inactivity (**Figure 4-19**). For the next steps it should be defined which functional geriatric tests are the most applicable to be an “early detection tool” and a reliable condition measurement among elderly citizens.

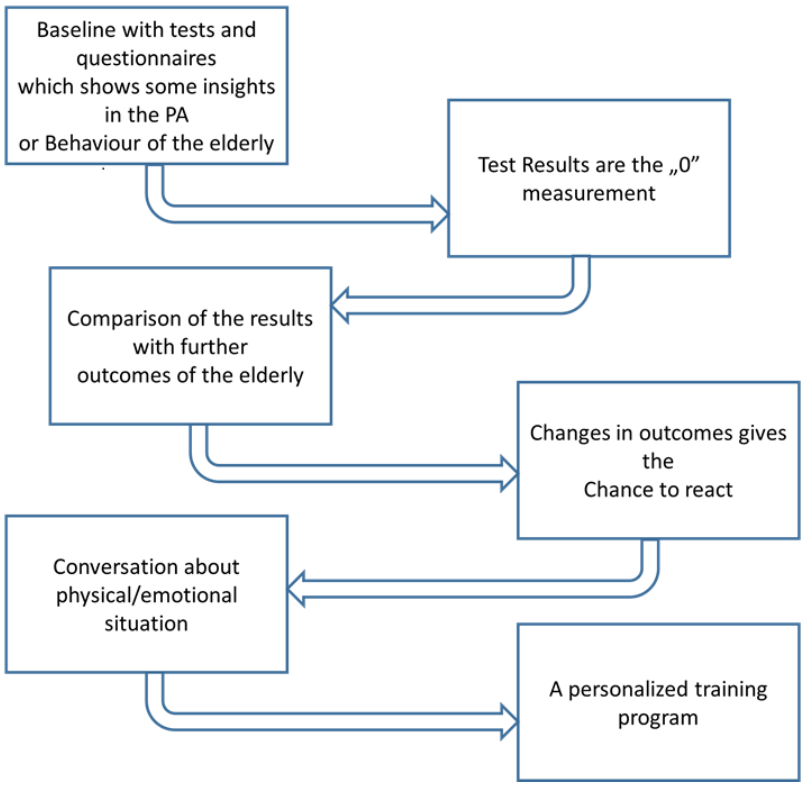

Figure 4-19: Personalized training program roadmap

5 Conclusion and Roadmap

In this deliverable report, the participating partners integrated, implemented and executed different tests and trials in different use case settings and in different locations. These trials targeted different Touchpoints of the REACH project and furthermore they targeted different aspects to be implemented in this project e.g. Data Collection and Analysis using Machine Learning, Ambient and Wearable Sensors, Sensor Fusion and Implementation, Personalization Strategies and Motivational Strategies. In each section and considering each Touchpoint the shortcomings and loopholes were addressed for the next trials and integrations. Additionally, the results were also presented.

A general overview of the results and identified risks can be view in **Table 5-1**.

Table 5-1: Touchpoints and Targets

Touchpoint	Results	Identified shortcomings/risks
Touchpoint 1 Personal Mobility Device	– Training with activLife improves the 4-stage balance – ActivLife improves the 30sec chair stand test – Higher intervention possibilities – The Tinetti balance test, activLife intervention results in significantly lower results compared to physiotherapist intervention	– Intervention should start by individual involvement of a “sport coach” and develop toward new social and training habits – Activity Centers provide a great potential to be an “early detection center” for monitoring the level of activity among the elderly – An individual intervention program should be implemented quickly to protect the elderly against progressive inactivity
Touchpoint 2 Active Environment	– Collecting a rich data set for data analysis and machine learning algorithms – Covering and addressing the needs and requirements for an application to ethics commission – Implementing a test Active Environment using several sensors in the br2 laboratory apartment and addressing the needs and implementation	– Video capturing for data annotation and classifier generation – Synchronization of sensors via synchronization action – Data acquisition protocol for a step by step execution
Touchpoint 3 Socializing & Nutritional Monitoring + Intervention	– Implementing a product service system used to address challenges e.g., personalizing behavior change strategies, Technology acceptance and data collection	– Lack of technology acceptance among the elderly – Researchers spend considerable care to choose the products used in this investigation for user acceptance – Recruitment of older people to participate in a research study involving technology is challenge

As an outcome of the current deliverable report and in consideration and alignment with previously submitted deliverable reports, a series of trials were conducted by different sub groups of the REACH. The targeting Touchpoints for this work task included **TP1**, **TP2** and

TP3. Based on the gained experiences and the results gathered from trials, the partners will take the trials to the next stage. This will address and include the involved partners in each Touchpoint and each use case setting. For example, at the moment the involved partners in development of trial for **TP2** are preparing for the next step which is the data collection and testing with real patients at SK. In this phase, the SK is preparing the ethics commission application and FIAIS is working on preparing the data annotation and defining the classifiers and TUM is working on sensor development for ambient monitoring. This trial will take place in the first half of 2019. In context of **TP1** and targeting the next steps, it should be defined which functional geriatric tests are the most applicable for a “early detection tool” and a reliable condition measurement among elderly citizens. Finally, in context of **TP3**, the involved partners will improve the elderly integration with the technology to improve the motivation and participation rate of elderly citizens in such studies.

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Appendix

Appendix 1

Unsigned data collection agreement/consent forms in German language.

Technische Universität München

Pflichtangaben für Fotos

1. Was ist auf dem Bild zu sehen:

   Die Versuchswohnung des Lehrstuhls, sowie die Testperson und verschiedene anderen Projektbeteiligten, die beim Laborversuch anwesend sind. Es handelt sich bei den Fotos um Einzelpersonenfotos, sowie Gruppenfotos.

2. Standort, Fakultät, Lehrstuhl, Labor:

   TU München, Lehrstuhl für Baurealisierung und Baurobotik, Arcisstraße 21, 80333 München

3. Datum/Urzeit:

   05.09.2018 von 09:30 Uhr bis 19:00 Uhr

4. Fotograf:

   Mitarbeiter der TUM, sowie Projektpartner des Projektes REACH

Einwilligung:
1. Die TU München, sowie die Projektpartner des Projektes REACH, dürfen die hier beschriebenen Bilder meiner Person zeitlich und örtlich unbeschränkt in ihren Medien (Internet und Print) nutzen für:

a) für die Berichterstattung über das Ereignis oder das Projekt, zu dem das Bild gemacht wurde.

b) für die Bewerbung eines ähnlichen Ereignisses oder Projektes zum Beispiel in einem Flyer oder im Internet.

c) für Imagebroschüren oder Flyern zur Bewerbung von Studiengängen.

d) für Publikationen in Fachzeitschriften (Journals) und auf Konferenzen.

2. Die Fotos dürfen an die Presse werden, zum Zweck der aktuellen Berichterstattung über die TU München und des Projektes REACH.

Datum: ..... Name in Blockschrift .....

Unterschrift:.....

Einwilligungserklärung

Ich bin damit einverstanden, dass meine Daten der TUM zu folgenden Zwecken erhoben, verarbeitet und genutzt sowie an Projektpartner des Projektkonsortiums REACH weitergegeben bzw. übermittelt und dort ebenfalls zu den folgenden Zwecken verarbeitet und genutzt werden:

Die gesammelten Daten werden gespeichert, um eine Datenbank zu erstellen, die es Softwareentwicklern und Datenanalytikern ermöglicht, Programme zu erstellen, die die Selbständigkeit und Unabhängigkeit von Kranken und Senioren in Zukunft verbessern sollen. Zu diesem Zweck werden die gesammelten Daten anonymisiert und für Projektpartner zugänglich gemacht, damit diese entsprechende Programme erstellen können, um die Aktivität, Essensaufnahme, Trinkverhalten und Hygiene einer beliebigen Person mit Hilfe von umgebungsintegrierten und Körper-Sensoren zu detektieren. Es ist nicht geplant, dass die Daten zu einem späteren Zeitpunkt gelöscht werden.

Ich bin darauf hingewiesen worden, dass die im Rahmen der vorstehend genannten Zwecke erhobenen persönlichen Daten meiner Person unter Beachtung des Bayerischen Datenschutzgesetzes (BayDSG), erhoben, verarbeitet, genutzt und übermittelt werden.

Ich bin zudem darauf hingewiesen worden, dass die Erhebung, Verarbeitung und Nutzung meiner Daten auf freiwilliger Basis erfolgt. Ferner, dass ich mein Einverständnis ohne für mich nachteilige Folgen verweigern bzw. jederzeit mit Wirkung für die Zukunft widerrufen kann. Meine Widerrufserklärung werde ich richten an:

Technische Universität München; Jörg Güttler, Lehrstuhl für Baurealisierung und Baurobotik, Arcisstraße 21, 80333 München; E-Mail: joerg.guettler@br2.ar.tum.de

Im Fall des Widerrufs werden mit dem Zugang meiner Widerrufserklärung meine Daten sowohl an der TUM als auch bei allen Projektpartnern, die Zugriff auf die Daten erhalten haben, gelöscht.

Vorname/Name: .....

_____ _____

Ort, Datum Unterschrift

Appendix 2

ACQUISITION PROTOCOL FOR ACTIVITY DATA

OUTLINE

Duration	Approximately 12-14 minutes
Target Activities	Drinking (with variations), taking a pill, writing onto a sheet of paper, interacting with a smartphone, dressing with pants, hygienic activities in the bathroom, eating, positions in bed
Degrees of freedom	***Loosely scripted acquisition protocol:*** • The high-level sequence of events needs to be strictly followed (unless otherwise stated). • There are only minor directives concerning the way how individual actions shall be executed.
Setting description	A (fake) one-room apartment with a separate bathroom. The apartment contains a bed, a table with a chair, and a cupboard. The bathroom includes a sink, a mirror and a toilet.
Sensor equipment	• Myo© armband (2 pc.), including an Inertial Measurement Unit and EMG electrodes • ActivePal© sensor (7 pc.), including a 3-axis accelerometer • Smartcardia© sensor (1 pc.), including a 3-axis accelerometer • Smartphone (including a full Inertial Measurement Unit with a gyro) • A mattress pressure sensor (1 pc.) • Four 4k stationary video cameras • A hand camera
Sensor on-body positioning	• Left and right lower arm (Myo) • Left and right upper arm (ActivePal) • Chest (Smartphone, ActivePal and Smartcardia) • Right and left upper, and right and left lower leg (ActivePal)
Participants	At least 4 participants
Subject characterization	All subjects have healthy condition and no constraints with respect to the set of activities to be performed. *Additional details:* • **X** females, **Y** male participants o **Gender, age, height, weight of each participant, left or right handedness**
Runs	4 ADL runs + 1 Drill run (incl. 10 repetitions) per participant
Synchronization	Synchro procedure (suitable for each type/position of sensor) to synchronize sensor measurements with video recording
Staff involved (in addition to the subject being monitored and measured)	• Instructor • Observer (making notes) • Camera man (note: try to avoid occlusion) • 2 technical assistants (with the following tasks) o Controlling functionality of cameras

	○ Controlling functionality of sensors ○ Manage the data after measuring (assign proper names to files, etc.)
Logging tool	• Video recording of the performed activities • Textual notes by the observer about constraints and special conditions (e.g. deviation from the activity protocol script)
Additional equipment	*Stage props:* • Glass of water • Fake pill box • Fake pills (liquorice) • Sheet of paper (a college block) • Pencil • Dishes (two plates, fork, knife) • Food (cookies and a piece of bread) • Smartphone • Tooth brush • Towel • Soap • Hair comb / brush • Toilet paper *Technical equipment:* • Two laptops for streaming sensor data from Myo bands • One laptop or college block for the observer to make notes • Light sources to enlighten the scenery

DATA PRIVACY

All subjects fully agree to the conditions of data acquisition outlined in this document. In addition, all subjects agree to the processing of the collected datasets as well as the use of the video footage for the purpose of data annotation and data analysis in the scope of this experiment.

It is important to have subjects sign and document their approval.

NAMING CONVENTIONS

- Each participant receives a unique subject identifier ("S1" for subject 1).
- Each session receives a unique session identifier. "S1 ADL 1" for (subject 1, ADL run 1), or "S1 DR 1" for (subject 1, Drill run 1).
- Across all sessions:
  - Each camera receives a unique number.
  - Each sensor receives a unique identifier.
- Each session will be documented with a standardized protocol file filled out by the observer.

DATA MANAGEMENT

The data will be collected either on the sensor devices (Smartcardia, ActivePal, cameras) or via wireless communication on two laptops (mattress sensor, Myo). After the session ends, all of the data will be transferred to a central storage device, using only local transfer methods, i.e. without using access to the internet.

The further handling of the data needs to be documented separately from this protocol.

ACTIVITY PROTOCOL SCRIPT

ADL RUN

HIGH-LEVEL DESCRIPTION

The ADL session was designed to incorporate some typical human activities and object interactions that may happen during the daily routines of patients in a hospital. This includes general locomotion inside the room, morning activities, hygienic activities, taking medicine, as well as drinking and eating.

1. *Morning phase (at bed place)*

The subject starts the session by mimicking sleeping overnight by *laying down into the bed*. He/she rests there for a short moment (taking on different *sleeping positions*), before becoming active again as usually done during the wake-up phase. During that phase, the subject still stays inside the bed, but *sits up at the top side of the bed*, and *plays around with a smartphone* that was located next to the bed. In addition, the subject should pretend to *make a short telephone call*. After this short active phase inside the bed, the subject is supposed to *leave the bed* and *get dressed with pants*.

2. *Morning phase (continued at the bathroom)*

The subject leaves the place with the bed and *enters the bathroom*. Inside the bathroom, the subject is free to execute a set of *hygienic activities* in an arbitrary order. These activities include *washing hands*, *brushing teeth*, *use a hair comb*, and *taking a seat on the toilet*.

3. *Short contemplation phase (at the table)*

The subject leaves the bathroom and *crosses the room* towards the table in order to take a seat. This requires moving the chair appropriately. He/she then *sits down* and *takes a sip* from a glass of water in front of him/her. Next, the subject takes a pencil and *writes* down some short notes onto a sheet of paper.

4. *Activities triggered by someone at the door*

While the subject is still sitting at the table, someone knocks at the door. The subjects *leaves* the table and *opens the door*. First, he/she receives a tray with food from some person outside. The subject takes the tray, *carries* it over to the table, and then returns to the door. There, the subject *receives* a plate with cookies. He/she then *closes the door*, *carries the plate* to a cupboard opposite to the table, leaves the plate there, and returns to the table to *take a seat* again.

5. *Eating, drinking, and taking a pill*

Back at the table, the subject first *eats with cutlery*, then *takes a pill* and finishes with *drinking* from a glass of water. All of these activities should be carried out in a natural way, with some short breaks during the transitions.

6. *Closing the session by eating a cookie*

The subject takes the water glass and leaves the table. He/she then crosses the room to go to the cupboard with the plate of cookies, while *carrying the glass* with him/her. When standing next to the cupboard, the session will be closed by first *eating* one of the cookies, and then *drinking* from the glass of water.

NOTES

- **Follow the instructions by the stage supervisor**. He/she is supposed to impose the time schedule. In order to execute all 20 planned ADL/Drill Runs, the time schedule has to be tightly followed throughout all three days.
- **Work in a concentrated and efficient manner**.
- Hold silence during the data collection sections. Avoid jokes and comments to keep up the concentration level.
- **Make sure that staff does not block the camera views**
- **After sensors are taken off from the subject, all persons except from the technicians leave the test flat**. This is to ensure the technicians efficient working, i.e. to avoid errors while collecting all the data from the sensors and checking them.
- **Persons off-stage should also be focused and concentrated**, to show support for the people on stage.
- **Observer, instructor and subject discuss the observer's protocol off the stage to complete it**.
- **Copy all sensor files and videos into the given folder structure** (keep care of subfolders. They serve to avoid the necessity of renaming files.)
- Start session with shoes taken off

ACTION SEQUENCE TO FOLLOW

Start of session

1. Check all equipment, wait for okay of technical assistants
2. Hold up sheet of paper with session identifier into the cameras. (Note: Someone has to do this in the bathroom, too).
3. **Perform synchronization procedure**

Morning phase (at bed place)

4. Go to the bed
5. Get into the bed
    a. Lay down
    b. Mimick sleeping (each position at least 10 seconds)
        i. Lay on your left body side
        ii. Lay on your back
        iii. Lay on your right body side
        iv. Turn from your right to your left body side
    c. Wake up
    d. Sit up in the bed (inside the bed)
    e. Grasp the smartphone
    f. Write a short text message
    g. Make a short telephone call
    h. Put the smartphone by side
    i. Stand up from bed
6. Take on pants
7. Take on shoes

Morning phase (at the bathroom)

8. Go to the bathroom
9. Enter the bathroom and **Perform synchronization procedure**
10. Execute the following activities (free choice of execution)
    a. Wash the hands at the sink
    b. Dry your hands with a towel
    c. Brush the teeth
    d. Brush the hair
    e. Sit on toilet (open, sit down, stand up, and close)
11. **Perform synchronization procedure** and leave the bathroom

Contemplation phase (at the table)

12. Go to the table
    a. Choose a chair and approach it
13. Taking a chair for sitting down
    a. Move the chair in order to be able to sit down
    b. Sit down naturally
14. Drinking I (vary hands)
    a. Take the glass of water
    b. Take a sip
    c. Put the glass back to the table

15. Writing down some notes or draw any sketch
    a. Take a pencil and the college block
    b. Think for a little while
    c. Note down some thoughts or draw
    d. Place back pencil and college block to their origins
16. Relaxing for a few seconds
    a. Get yourself into some comfortable position

Someone at the door

17. Someone knocks on the door
18. Go and open the door
19. Take tray with food
20. Carry tray to the table (Note: Instructor holds door open to stop automatic closing)
21. Return to the door
22. Take plate with cookies
23. Close the door
24. Carry cookies to the cupboard and place there

Eating, drinking and taking a pill

25. Return to the table
26. Choose a chair and approach it
27. Taking a chair for sitting down
    a. Move the chair in order to be able to sit down
    b. Sit down naturally
28. Eat with dish, fork and knife
29. Taking a pill
    a. Take the pillbox
    b. Open the pillbox
    c. Take one pill out of the box
    d. Eat the pill
30. Drinking II (left and right hand allowed)
    a. Take the glass of water
    b. Hold the glass for a certain time while looking through the windows
    c. Take a sip or tow
    d. Place back the glass to the table

Having a cookie and a drink

31. Stand up from the table and take the glass with you
32. Go to the cupboard
33. Keep the glass in your hand
34. Eat a cookie while standing
35. Drinking III (while standing, left and right hand allowed)
    a. Take a sip or tow
36. Put glass onto the cupboard to have your hands free

Session closing

37. **Perform synchronization procedure** to finish the session

DRILL RUN

Each participant needs to perform the following activity sequence with short breaks in-between 8 times (partitioned into two separate sessions DR I, DR II):

1. **Check all equipment, wait for okay of technical assistants**
2. **Hold up sheet of paper with session identifier into the cameras. (Note: Someone has to do this in the bathroom, too).**
3. **Synchronization gesture in apartment and bathroom (at start, middle and end of a session)**

- Take on pants (without shoes) [first session sitting, second session standing]
- Go to the toilet
    - Open closet
    - Pull down pants
    - Sit
    - Grasp paper
    - Reach body forward and hand backwards to mimick cleaning
    - Pull up pants
    - Close closet and flush
- Wash your hands (use soap, position of soap can be altered)
- Put tooth paste on tooth brush
- Brush teeth (including spit out)
- Dry your hands with the towel
- Brush hair (not more than 18 secs)
- Sit down at the table
- Drink (variations allowed, two per run) [with both hands]
- Eat with fork and knife (not more than 15 secs)
- Take pill(s) from the pill box (vary number)

Take off pants and start again

Estimated length of the sequence should be 4.5 minutes (equaling less than 20 minutes per drill run session, based on 4 repetitions). Note that the current cameras will stop recording after 20 minutes.