This document reports on the progress for the EXPERIMEDIA experiment 3DRSBA, following on the initial report on experiment problem statement and requirements.

It contains the information about the current situation including explanations for each area.
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<tr>
<td><strong>Full title</strong></td>
<td>Experiments in live social and networked media experiences</td>
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<tr>
<td><strong>Grant agreement number</strong></td>
<td>287966</td>
</tr>
<tr>
<td><strong>Funding scheme</strong></td>
<td>Large-scale Integrating Project (IP)</td>
</tr>
<tr>
<td><strong>Work programme topic</strong></td>
<td>Objective ICT-2011.1.6 Future Internet Research and Experimentation (FIRE)</td>
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<tr>
<td><strong>Project start date</strong></td>
<td>2011-10-01</td>
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<td><strong>Project duration</strong></td>
<td>36 months</td>
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<td><strong>Activity</strong></td>
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<td><strong>Workpackage 4.13</strong></td>
<td>EX13 - 3DRSBA: 3D Remote Sports Biomechanics Analysis</td>
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<td><strong>Deliverable lead organisation</strong></td>
<td>Qualisys</td>
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<tr>
<td><strong>Version</strong></td>
<td>1.0</td>
</tr>
<tr>
<td><strong>Status</strong></td>
<td>Final</td>
</tr>
<tr>
<td><strong>Dissemination level</strong></td>
<td>PU: Public</td>
</tr>
<tr>
<td><strong>Due date</strong></td>
<td>PM31 (2014-04-30)</td>
</tr>
<tr>
<td><strong>Delivery date</strong></td>
<td>2014-05-28</td>
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Appendix D.

External document: "D4.13.2 3DRSBA Experiment Progress Report_Annex D.pdf"
1. Introduction

This deliverable reports on the progress of the EXPERIMEDIA experiment of **3D Remote Sports Biomechanic Analysis** (3DRSBA). It follows the experiment description given in "D4.13.1 - 3DRSBA Experiment Problem Statement and Requirements", and comments on the different areas described.

The goal of 3DRSBA is to bring biomechanical analysis to the athlete in order to facilitate screening for possible risk of lesions. It is based on the clinical need of injury prevention in athletes associated with intense training routines.

The experiment is using modern technology used in biomechanical laboratories and taken off to new areas, such the training field, by using fast internet connections and modern multimedia and remote control tools.

The experiment itself consists of three general components:

- The feasibility to use remote control techniques in biomechanical analysis;
- The clinical viability of this approach, including clients satisfaction;
- The easier presentation of such complex biomechanical data to non-experts.
2. Experiment Architecture and Implementation

The experiment consists of several stages:

1) Installation of a modern 3D-capture system at CAR. The initial setup is situated in the biomechanical laboratory at CAR and integrating with other existing systems. The integration is necessary for the validation of the biomechanical model before it can be used in the field. (Figure 1)

![Figure 1: A set of IR cameras (upper right) are capturing markers (upper left). The control programme is transferring the 3D data of a single marker included in a biomechanical model to 3D motion information as seen at the bottom.](image)

2) Development of a biomechanical model, which could be used outside the laboratory without the usual additional systems available at the lab, but with consistency in the data.

3) Integration of capture setup with the core components of EXPERIMEDIA (Figure 2).

4) Initial testing of the setup inside the laboratory, including the remote control test from an outside location.

5) Fine-tuning of the model and designing of the Project Automated Framework (PAF) for fast preparation of the data (Figure 3).

6) Data collection in real-time situation and analysis.
Figure 2: Integration of Experiment setup with EXPERIMEDIA core components.

Figure 3: Shows the full 3D workflow processing the 3D data from image to analysis.
3. Experiment Progress

A data-protection agreement between all partners of the project has been designed and signed, including the definitions of the project and the ethical considerations. Special consideration has been taken into account related to privacy of the individual and the dissemination interest of EXPERIMEDIA. A project related confidentiality agreement for the athletes has been designed and implemented. (D4.13.2 3DRSBA Experiment Progress Report_Annex C.pdf)

The project has been concretised between partners and the work-plan has been fine-tuned. This included the experiment itself as well as the inclusion of the EXPERIMEDIA work frame (Figure 2). The QoE integration will use the Lime-survey pack from EXPERIMEDIA for a questionnaire. The QoS integration will use Version 2 of the ECC, recently presented. Integration into the Qualisys software and the necessary programming is studied to date. An initial version will be used with the first Process-Automated Framework (PAF) version.

The initial set-up of the 3D capture system has been done. Integration with existing hardware at CAR has produced slight delays, which have been overcome. Those delays were also due to the need that the initial Wi-Fi connection with the capture computer running a new system version needed specialised IT installations. With support from the IT department at CAR those problems had been solved. The system is now fully functional.

The experiment procedures as stated in deliverable D4.13.1 have been initiated and the current situation is presented in the following listing:

Remote control

1) Familiarisation with the 3D system and the biomechanical software packages necessary to treat the data.

The setup of the system at CAR had been done. Integration of the system into the existing systems at CAR had produced a slight delay, but had been resolved to full satisfaction for all participants. This includes:

- The set-up of the cameras and for determining the best positions and settings for the local situation at the biomechanics laboratory;
- The connection with the local force-plates and the synchronisation with the cameras;
- Installation of capture programme (QTS), Camera server (QTM server), modelling Software (Visual 3D), Remote control (teamviewer), connection with AD controller and related software;
- Defining and establishing the general and local co-ordinate systems and quality checks, including test capture sessions;
- Familiarisation of all operators with all distinctive software packages. The complexity of those packages leads this to be continuous process;
- Establishing the initial approach for the PAF development.
For easier familiarisation with the automated process routines Qualisys has developed in other occasions, a running PAF was provided to CAR. Subsequent hardware changes were initiated by the biomechanics laboratory at their treadmill for increasing capture quality. It also allowed using the system for directly with athletes (Figure 4).

![Figure 4: Running athlete at the left and QTM PAF at the right: First column represents the PAF Framework with structure and indicators of procedures done (green) and missing (red). In the middle is the model representation with automated marker recognition at the right column.](image)

2) **Testing the remote control protocol relating to the amount of data transmitted and the effects of transmission delays on the experiment.**

Initial tests were performed, including connections to outside locations (expert consultation and support) as well as using the high speed network capabilities at CAR. The results were very promising and have directed Qualisys to continue the development of two applications for Apple/Android and adapt those both for improving the support possibilities for the biomechanist at the Motion laboratory when an outside operator is using the system, e.g. at the training site.

The first application (**viewfinder**: Figure 5) allows the remote access to each individual capture-camera. It has the options to zoom in to the capture space as well as allowing the user to change the camera settings remotely for better capture quality. Information about the camera identification as well as the amount of markers visible is shown on the screen.
The second application (QTM remote: Figure 6) has been adapted for remotely controlling the capturing process. Originally, the capture is initiated by either pressing a button on the capture PC or having a press-button connected to a defined camera. The new application allows the independent connection using Wi-Fi connection providing the control person to be best positioned for the capture process, e.g. supervising the capture from different angles with the need of going back and forward to the PC to start the sequence.

Figure 5: QTM viewfinder with display of markers within the capture space (right) and options to change camera parameters (left).

Figure 6: QTM remote: Application for initiating and stopping the capture. The event marker can be used to define important moments in the capture.
Whilst both applications have been tested for functionality, it will also be tested for improving the handling of the system for the screening project.

3) **Setting up single and multiple sites to test the effect of such approach on the biomechanical expert.**

This part is not yet initiated. The current side of testing is within the biomechanics laboratory. Once the model and the first stage of automation are established, the system will be tested under different light conditions in order to determine working conditions.

**Biomechanical Model**

1) **Evaluation of current screening methods available.**

In Appendix C the most important scientific articles are listed. Related to the experience gained by CAR for screening procedures, the scientific baseline has been established in the first months of the project. Several aspects are noted:

- Several centres in the world are interested in the screening process for risk factors of lesions at the knee;
- Several, but no uniform methods are tested;
- There is no general gold standard established;
- Strong indication is given for the type of motion to be performed by the athlete in order to achieve adequate data: Drop Jumps (DJ) and Side cutting (SC) manoeuvres;
- No fixed marker-set for optical systems has been established as best suited, but one has been found which included a profound test-retest protocol.

Especially the last point is important, as it improves the quality of reproducibility and data validity (Robinson et al). For the screening project it also provides an excellent starting point for the modelling, as the type and amount of validity studies can be reduced at CAR. This gains time in the project-workflow, whilst not compromising scientific quality.

Therefore, an initial test protocol, including a marker-set, has been established on which an iterative approach can be used in defining the threshold of injury risk by CAR. In this process the area between low risk group and high risk group can be narrowed down in the future. This allows the screening to be used from the beginning whilst at the same time staying on the safe side, clinically. As current models mentioned in the literature are only tested inside the biomechanics laboratory, it has been decided that the Project Automated Framework (PAF) to be developed should be applicable in both situations, either outside or inside. This would facilitate the future development of the screening tool by CAR outside EXPERIMEDIA, and also allow improving the clinical analysis and the comparison of the data.

2) **Evaluation of existing protocols for the use in the screening process.**

As for the screening methods, little consistent information has been found for the protocols used in screening. Based on the experience at CAR and information from other scientific centres
being contacted had established a draft version of the protocol. This protocol includes information about:

- Structure of the screening process, including:
  - System preparation including set-up and calibration;
  - Preparation for the athlete (marker placements, warm-up);
  - Test manoeuvres (number and times);
  - Analysis workflow.

- Quality assurance guidelines for the measurements;
- The marker placement mapping;
- Model description and calibration;
- Scientific background to the statements made in the protocol.

The screening protocol will include all the details about the methodology being used, but not about the clinical reasoning at the analysis, as this depends on the expert using the system as well as the additional data available. To facilitate the latter, a clinical questionnaire will be provided using the lime-survey tool of EXPERIMEDIA, as it is explained in the chapter about the core components.

Two major aspects have to be considered in the model used within the screening protocol: First the general relation between superficial marker position and underlying anatomy, and secondly the application on each athlete. The process responsible for the latter is the nominated quality assurance. This also includes a guideline for increase reproducibility of the data.

3) **Initial test with hardware/system.**

Besides the general hardware test, as explained earlier, specific hardware/functional tests were performed in order to set a baseline for the development of the specific screening protocol. In this process, 12 capture session (7 male, 5 female) with a minimum of two hours each was performed inside the motion laboratory. These capture sessions served the purpose of aligning the system with the expected motion patterns of the screening protocol (jumping, side cutting, frontal de-acceleration and reverse movements) as well as gaining experience with different marker set up's and positioning on the human body for best capture results.

4) **Developing the screening routine.**

The protocol of the screening protocol includes the definition of the motion best fitted to detect alterations at knee level, indicating injury risk factor for best analysis and risk detection. From literature review as well as previous experience at CAR with video analysis, two movements were selected to be most suited. The first one is a so called drop jump, which is a vertical jump from a high of about 30-50cm. The second, called side-cutting, is a motion when running in one direction is changed suddenly, changing direction on a single leg and moving sideways. The first one has been chosen for previous experience, whilst the latter was chosen for the increased changes on the knee control. Whilst this provides better data as the drop jump, only 3D
measurements are able to measure it precisely. The number of repetitions and the prior warm-up also has to be established in the protocol.

Based on the aforementioned tests, including the 120 captures, parallel development lines were initiated. The first dealt with the questions regarding the marker placement and analysis results, whilst the second one investigated quality control mechanisms and model variations.

Figure 7 shows the first part of the capture process until the modelling stage. In this stage the relation between anatomy and model representation needs to be established, in Figure 8 two aspects are shown. The set-up is using the marker set as seen in Annex A.1.

A first draft of the protocol has been established and the development of the procedures used for data preparation and data presentation (PAF) has been initiated. This version requires testing which is now initiated at CAR. As the details of the PAF are of strong commercial interest, the
material is dealt with confidentially between CAR and Qualisys. Documentation of the process is hosted at CAR.

Visualisation

8) Once the model (including marker placement is fixed), a visualisation protocol will be established. This includes the visualisation details for the avatar, the amount and type of additional data and presentation.

The integration with the 3DCC component has been initiated. The idea is to provide a better presentation for the end-user by using this EXPERIMEDIA component. However, there are aspects which suggest incompatibility. This is due to the different marker configurations used for biomechanical modelling and animation, the latter necessary for avatar creation. As the intention of the biomechanical model is to be as less demanding as possible, the use of additional markers in order to improve the generation of the avatar would increase a preparation time for the capture and more time for the athlete to be tested. Intentions are made to overcome this situation, but chances are limited.

However, as for the general presentation of the data, the PAF packaged will include graphs with 3D imaged for clinical assessment. The necessary information to be presented is in development.

9) Establishing initial design.

This is in progress and forms an integral part of the PAF development.

10) Developing system and testing.

Following the first set-up and PAF, this will be an iterative process within the PAF development.

Integration with core-components

The integration with the EXPERIMEDIA core components has been initialised with different results. Integration into the ECC includes the different aspects for QoE and QoS.

For the QoE a survey conducted through Lime Survey has been developed (Appendix B). This will investigate the user acceptance regarding the screening procedure. At the GA at CAR, it was proposed to go back to the initial plan of using the Babylon interface. As this might improve the data connection between QoS and QoE this was accepted and will be developed further. The original concept of QoS integration will be adapted to the new structure. The exact definitions on the metadata to be used were also dependent on the outcome information of the biomechanical model; therefore complete integration had to wait until this stage.

The use of Lime Survey will be changed to be used for clinical analysis at CAR. Based on a clinical questionnaire for the athletes, the motion analysis can related to the situation of wellbeing of the athlete. This will facilitate the workflow at the clinical service at CAR and also improve the analytical outcome of the screening process.
The use of the 3DCC component for use in visualisation is still in discussion, as the first results did not show improvement over the current commercial product used (Visual 3D). This has been discussed at the GA at CAR and a new proposal is investigated by Qualisys.

Dissemination

Dissemination of the experiment has been started. It was presented by Ventura Ferrer (Biomechanics Lab, CAR) at the XXIII International Conference on Sports Rehabilitation and Traumatology, organised in Milan in March 22-24.

The system has also been used as a training tool in the education for master students for several regional Universities (University of Barcelona, Gimbernat, Blanquerna, Ramon Llull). Olympic Committee coaches trained at CAR were also introduced to the system and its capabilities.

The setup and the function of the remote components were successfully presented at the GA at CAR in May 2014. This demonstration also included the remote life demonstration for calibration, capturing and processing the screening data.
4. Future Plans

Having established the model and methodological needs for the screening process, a first automated process-pipeline will be created. This protocol will be tested in July with two football clubs in the intended manner. Prior to this, the function of the protocol will be tested within the biomechanics laboratory. These tests include the system set-up outside the laboratory.

With the first version of the pipeline, the integration with the ECC can be implemented and tested. This includes a QoE/QoS-Babylon application (tablet), measuring the timing values for each athlete at the test and a small questionnaire of user acceptance at the end of the test. The questionnaire will be adapted, as Babylon cannot use text fields and writing on a tablet is limited compared with using a keyboard in a web based application.

Further QoS data will be streamed coming from the Qualisys software and can be cross-referenced to the Babylon data.

Lime Survey will be used for an analytical questionnaire, improving the outcome quality from the screening. The treatment of this data type had been discussed with K.U.Leuven at the GA at CAR. It was established that this fits perfectly in the data-treatment procedures for the experiment. As this survey is more extensive than the original questionnaire, athletes will not be asked to fill it in at the screening side, but will be provided with the access information for later use. Therefore, the questionnaire is not used for the initial on-side conclusion, but for use in the final report send to the clubs. The methods to inform the biomechanical laboratory about questionnaires answered needs to be investigated. The goal is that the Laboratory will be informed whenever a questionnaire was filled out, so the information can be used in the analysis. At the questionnaire, an identifier will be used, which can only be used at CAR for the relation to the capture data.

As for the 3DCC, suggestion will be made quickly in the next development stages.

The remote control will be tested with the system at CAR, within the laboratory as well as in the field close to the athlete.
5. Conclusion

Even with the increased time needed to specify all details of the project, the experiment is well under way. Initial data on the scientific part are promising and continue to be optimised. The timing is within the work frame for the field tests in July.

Integration with the core components are in process and being under development.

The development of the PAF will already provide increased possibilities for commercial use. Besides the development of the biomechanical model, the user acceptance for the screening outside the laboratory is essential. Additionally, it will be compared to existing simple forms of screening using normal video. The relation between using a simple and quick, but imprecise system versus a complex, precise system with increased set-up time is to be evaluated in order to apply this methodology on a daily basis.

Dissemination will be when presenting the scientific results and the methodologies offered at CAR as well as from the commercial point of view for Qualisys offering a new commercial PAF to clients of the 3D system.
Appendix A. The biomechanical model

A.1. Marker Placement
Appendix B. Lime survey questions

B.1. English Version (Lime Survey includes Spanish translation)

1) Which type of sport are you training in? (Text or fields)
2) For how many years are you active in your sport? (Field)
3) Were the EXPERIMEDIA project (including the test) and its purpose explained to you? (1-5)
4) Was the explanation of the project to your satisfaction? (1-5)
5) Did the experiment and the explanations match? (1-5)
6) If not, what has been different? (Text)
7) Do you think that this type of screening-test would be beneficial to your sport? (1-5)
8) Do you think that this type of screening-test would improve the clinical service given at CAR? (1-5)
9) Do you think that this type of screening-test would be beneficial to you personally? (1-5)
10) Did you receive any biomechanical service before? (Yes/No)
11) If yes, how often per year? (1, 2, 3, more than 3)
12) Is the duration of the test acceptable? (1-5)
13) Was the warm-up time sufficient for you to be prepared? (Yes/No)
14) Did you find the test tiring for you? (Yes/No)
15) Did the test have negative influence to your training schedule? (Yes/No)
16) If yes, what would you change? (Text)
17) Do you believe that regular screening would help you in the process of preventing injuries? (1-5)
18) Any other remark you would like? (Text)
Appendix C.  List of most important literature for the model definition


Knudson DV. Authorship and sampling practice in selected biomechanics and sports science journals. Percept Mot Skills 2011;112(3):838–44.


