



SUBMISSION CLEANROOM AWARD

INNERSPACE CLEANROOM BEHAVIOR TRAINING

1. ABSTRACT

The "Innerspace Cleanroom Behavior Training" is intended to prepare employees optimally for key moments in the cleanroom using Virtual Reality technology. Virtual Reality glasses allow the employee to immerse himself in authentic cleanroom environments and to train the right behavior in key moments (such as cleanroom zone A interventions). The psychological principle of experience-based training can thus be realized outside of the actual cleanroom environment: Employees can gain authentic experiences in the clean room before they enter the real cleanroom for the first time. The innovation of the Innerspace Cleanroom Behavior Training is defined by two core elements: By (1.) "full-body-tracking" two basic factors for correct behavior in the cleanroom are mapped and measured exactly in Virtual Reality with movement speed and body-posture for the first time. The employee receives immediate feedback on misconduct (e.g., too fast movement or contamination by touch) through full-body-tracking during each lesson. Finally, the collected training data (2.) are systematically evaluated in the Training-Management-System (TMS). As a result, the training units can be individually adapted to the respective level of each employee (adaptive training) as well as statistics on the strengths and weaknesses of a training group. Furthermore, all training sessions in Virtual Reality can be viewed retroactively on the 2D screen. Similar to a video feedback, the coach here has the opportunity to analyze a training session from different camera perspectives and to support the employee so specifically.

Preview-Video: <https://vimeo.com/283456759>

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2. EXPERIENCE-BASED TRAINING AND SUSTAINABILITY/ EFFECTIVENESS

The low sustainability of training

Correct behavior in the cleanroom is essential to reduce the risks of contamination and to make the right decisions at decisive moments in the production process. In order to learn and maintain correct behaviors, high-quality trainings are essential. However, it is difficult to achieve lasting learning success, especially in the case of behavioral training. According to statistical estimates, only 10-35% of the training content is implemented in the long term (see Kauffeld, 2016). The potential for improvements in cleanroom behavior through new training methods is correspondingly high.

Three main factors for sustainable training effects

From the point of view of psychological research, self-made experience is the essential principle on which to build sustainable training success. Experience-based learning requires that the training environment and training tasks closely resemble reality. The higher the degree of reality of the training, the higher the learning transfer (into the cleanroom).

But a single learning experience is not enough to guarantee lasting training effects (Goldstein & Ford, 2002). It takes repetitions of training until the correct behavior is reliably implemented in the



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cleanroom. Repeatable training sessions become more effective the more the practice situations resemble reality in the cleanroom. Feedback helps to reflect on new experiences, to align learning progress with training goals and to improve deficits through exercises. Constructive is the feedback given immediately after the respective training exercise, which addresses both negative and positive aspects, is specifically formulated and takes account of individual needs (Taylor, Russ-Eft, & Chan, 2005). Experience-based learning, repeatable training sessions, and constructive feedback are three of the key drivers of high effectiveness.

Why seminars and e-learning are limited in their sustainability

Seminars and e-learning play a prominent role in teaching knowledge and skills about cleanroom behavior. However, their effectiveness is limited by two factors:

- 1. Learning content can only be taught based on experience in seminars / e-learning**
Whether learning video, online course or learning app: The employee cannot "experience" the learning content by himself. In the seminar setting, experience-based learning units can be implemented. In the context of learning correct cleanroom behavior, however, training scenarios with a high authenticity can only be simulated to a limited extent. In this way, it is only possible to realistically reconstruct those scenarios at high costs.
- 2. Experience-based training is not repeatable as often as needed**
Training has been proven to have a long-lasting effect if the sessions can be repeated regularly. However, seminars, in particular, are reaching their limits here because most of the learning scenarios cannot be repeated indefinitely for organizational reasons. As a result, the effective training time is limited to the seminar time. Regular repetition over months or individualized training sessions are not possible.

Experience-based Training in Virtual Reality

The sustainability of a cleanroom behavior training tool depends on how well it can map the three factors of experience-based training, repeatable training sessions, and constructive feedback.

For experience-based learning, Virtual Reality offers the decisive advantage that the virtual situation in the subjective experience of the user can potentially "feel real". The user believes the illusion that the events are really happening - in spite of the sure knowledge that nothing real is happening. Via the VR headset the user dives directly into the virtual 3D environment and experiences the cleanroom scenario from the virtual "first-person perspective". This fundamental aspect of VR to deliver an experience that gives rise to illusory sense of reality is what distinguishes it fundamentally from all other types of media.

However, the level of realism experienced depends on how much the Virtual Reality is similar to reality: In addition to the realism of the 3D optics and the genuineness of the training scenarios, the realism of the interaction is also important. In the cleanroom, even marginal errors in posture, movement speed and proper procedures can lead to contamination. The effectiveness of training in Virtual Reality therefore depends essentially on the accurate mapping of the physical body and all movements. However, standard high-end VR systems are not able to represent the full body of the user in VR. The tracking of the user is limited to the head and the two hands. If the user stood in VR in front of a virtual mirror, he would see only the VR glasses and the two controllers, but no body. The main disadvantage of this type of tracking is that the user's behavior and movement speeds cannot be reliably determined. Thus, two essential aspects for correct behavior in the cleanroom with standard VR hardware are not trainable. A sustainably effective Virtual Reality Training must therefore be able to map the body, movement speed and posture of the user exactly in Virtual Reality.



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3. THE INNOVATION OF INNERSPACE CLEANROOM BEHAVIOR TRAININGS

The Innerspace Cleanroom Behavior VR training innovation can be described in two aspects: Experience-based training and repeatable training sessions in Virtual Reality, integration of full-body tracking for correct movement and posture training with constructive training feedback and data-driven analysis with the Training-Management-System.

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A. Full Body Tracking as an Innovation for Cleanroom Behavior Training in VR

An integral part of the Innerspace Cleanroom Behavior VR training is full-body tracking for the training of correct movement and posture. Compared to other tracking methods, the Innerspace solution uses very little hardware: The user only needs three additional trackers, which are attached to the two feet and the lower back. Together with the VR glasses and the two controllers, there are six tracking points that allow the software to measure the body, posture and speed of movement and display them in real-time in Virtual Reality. The training design with full body tracking solution offers the following advantages:

- **Simple operation and high reliability:** After entering the body data (body size, shoulder width, arm and leg length) and applying the trackers, the software automatically scales the virtual avatar to the correct body dimensions of the user. The body data is linked to the user profile so that each employee can start training with their own avatar in a new session.
- **Increased sustainability through a strong sense of authenticity:** Accurate full-body tracking supports the subjective impression of being in one's own body in an authentic cleanroom scenario in Virtual Reality. Through the full-body tracking every learning unit wins in realism and is stored in a more sustainable memory.
- **Risk-free learning environment:** In sterile production, errors result in high cost and dangers. Often, it is difficult to create risk-free learning environments so that employees can rarely be prepared for real-world needs in a realistic manner. In Virtual Reality even dangerous and difficult cleanroom situations can be represented authentically.
- **Full body tracking for the training of movement sequences in the cleanroom:** The full body tracking solution allows both movement speed and body posture to be measured and trained reliably for the first time in each learning unit. This is not possible in seminars and on-the-job trainings. Learning units for handling difficult scenarios (e.g. interventions in cleanroom zone A or disinfection processes) can be extensively trained.
- **Instant feedback in the case of misconduct:** Full-body tracking allows the user to be immediately informed of any exceeding of the permissible body speed. For example, if the user moves his legs too fast during a learning session to cleanroom zone A, his legs will glow red. In addition, the user hears an error tone. Through this "instant feedback", the user can correct his own misconduct immediately. In addition, the user gets an overview in which scenarios he makes the most common mistakes and can prepare himself specifically for these. Main benefit is that behavioral deficits are identified and can be improved in the next session. Operators learn quickly from their mistakes and implement correct behavior more reliably in daily production



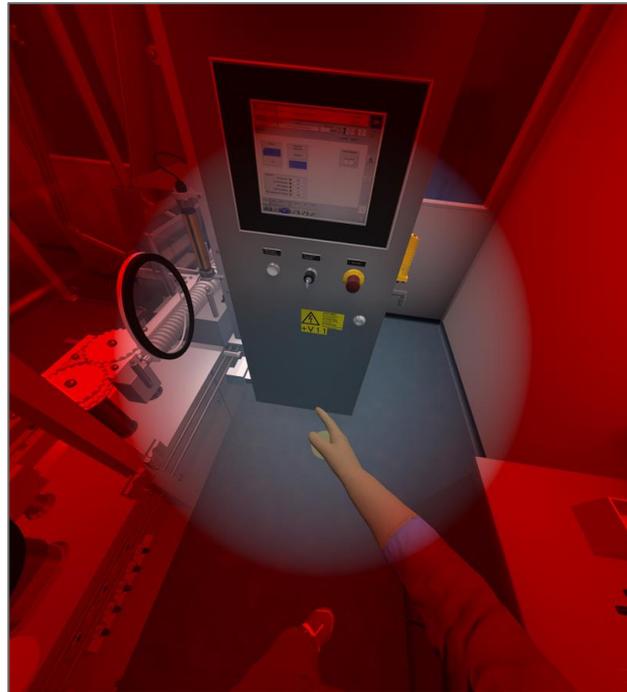
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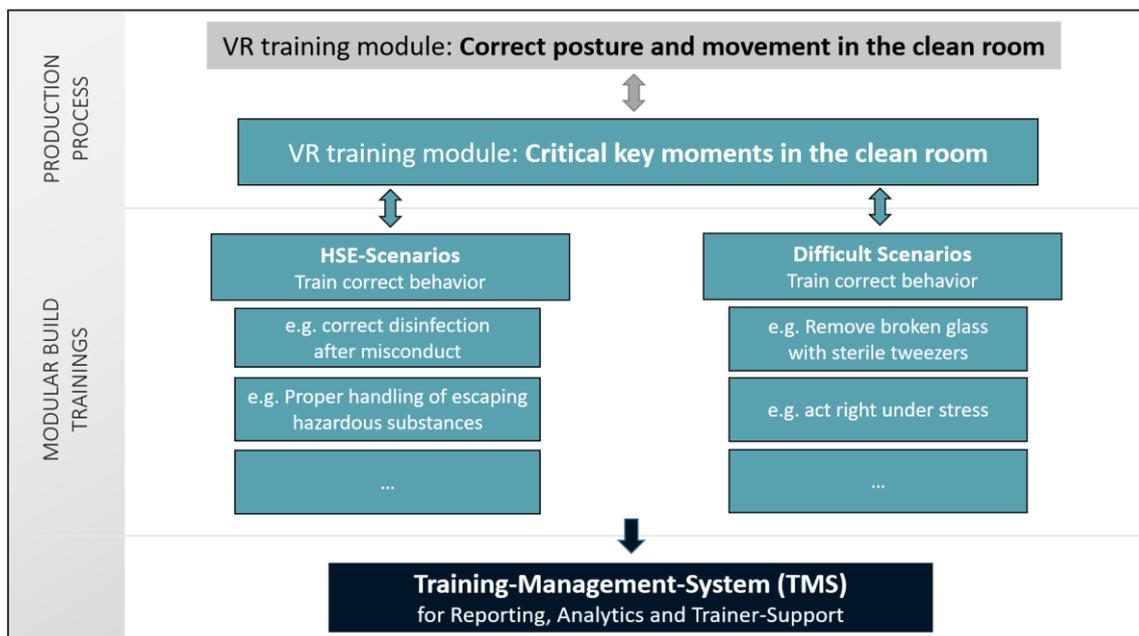
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Picture 1: Too fast movement speed from the first-person perspective in virtual reality



- **Correct behavior in key moments of the cleanroom:** Innerspace Cleanroom Behavior Trainings virtually confront operators with critical key moments in cleanrooms where most common mistakes occur – and allows them to make their own and learn from them. The Innerspace Cleanroom Behavior VR Training is modularly built around critical key moments in the cleanroom (e.g. “remove broken glass with sterile tweezers”).



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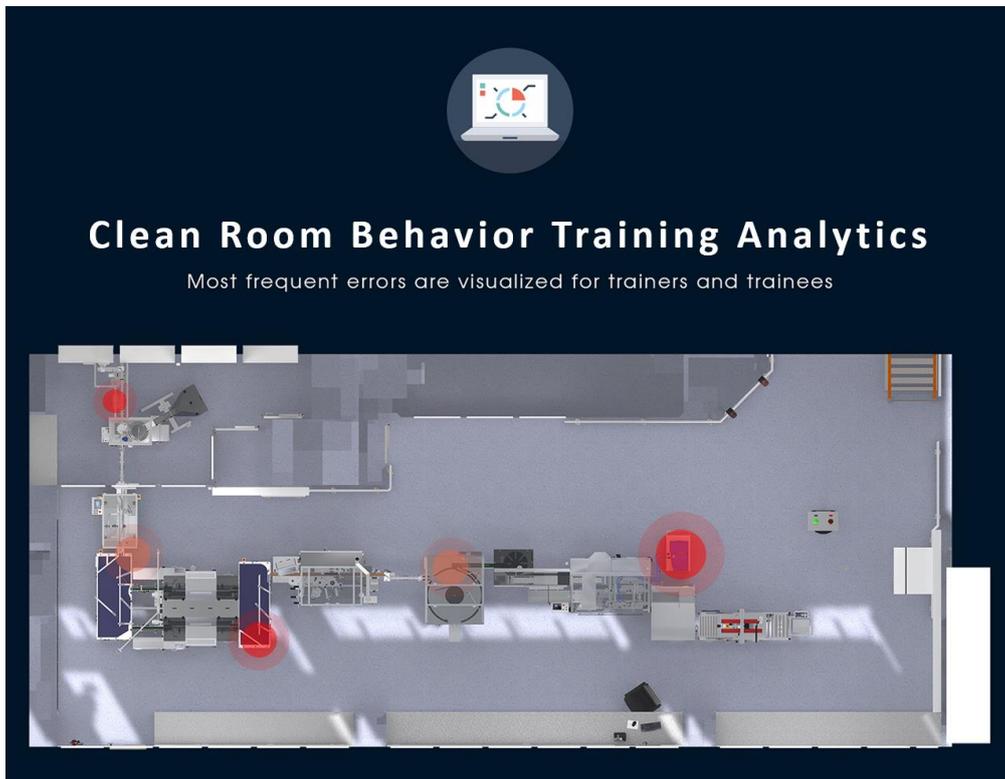
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B. Innovation through data-driven analysis with the Training-Management-System

Another innovative feature of the Innerspace Cleanroom Behavior application is the Training-Management-System (TMS), in which all training data can be managed and evaluated. For companies as well as for trainers the TMS offers the following advantages:

- **Systematic evaluation of training data and adaptive training:** All learning units for Innerspace Cleanroom Behavior Training are linked in the TMS with the underlying SOPs. If the trainee has completed a learning session, the evaluation function of the TMS displays directly which aspects of the SOP were carried out correctly and where there is still a need for training. In the following training session, the user can then specifically train those key moments that are still deficient. The training thus adapts to the individual weaknesses of the exerciser and can put these directly in relation to the SOPs. This lays the foundation for adaptive training for optimal training effects. Training data of each operator can be tracked and analyzed anonymized.
- **Reporting to health authorities:** At the press of a button, documentation of each training session and an overview about several trainings sessions can be printed out as PDF or directly submitted to authorities.
- **Statistics Training data for the improvement of the process sequences:** With the statistics function of the TMS the training data of all trainers can be evaluated. For example, companies can see in which training units the trainees on average make the most mistakes. One possible way of representation is the so-called "heat map".



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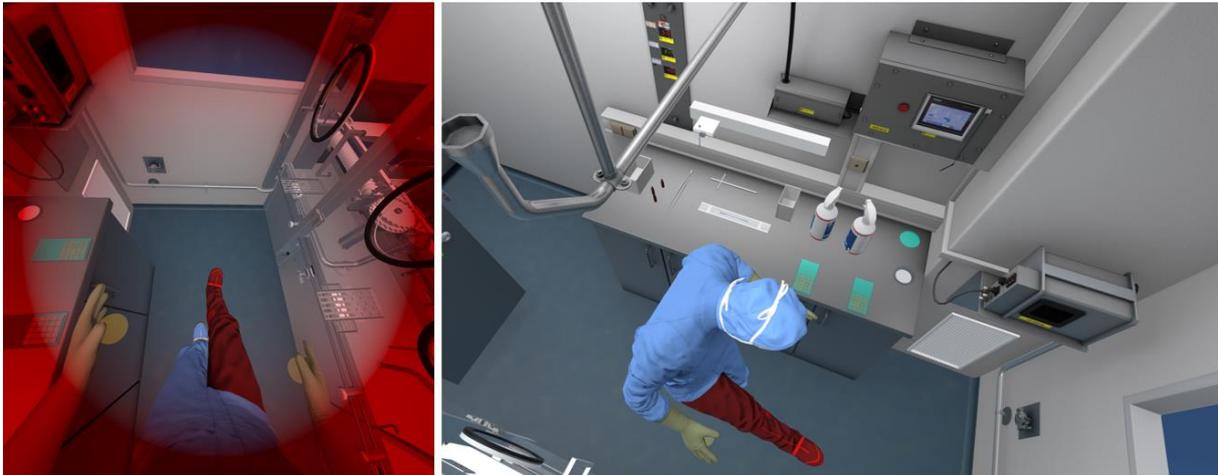
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- **Coaching-Mode:** The Innerspace Cleanroom Behavior application is designed to support coaches in the individual care of the cleanroom staff. For this purpose, there is a "coaching mode" in the TMS for the systematic follow-up of training sessions. Similar to video feedback, the trainer can review the employee's Virtual Reality training session and choose between different camera perspectives. In this way, behavioral mistakes can always be considered exactly from the optimal perspective. The coach mode also allows trainees to look at each other's training sessions and set meaningful goals for further cleanroom behavior training sessions

Coaching-Mode: Watching a training error from two different perspectives



C. Conclusion

The Innerspace Cleanroom Behavior VR training innovation offers two major innovations: The integration of full-body tracking for correct movement and posture training with constructive feedback into a Virtual Reality training. Through full-body tracking, experience-based training for correct behavior in cleanrooms can be trained for the first time in Virtual Reality. In addition, the data-driven analysis with the Training-Management-System provides a whole range of opportunities for improving the cleanroom production process and the professional coaching process.



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4. INNERSPACE – THE DEEP TRAINING COMPANY

Innerspace is a virtual reality training provider focused on learning of correct behavior in cleanrooms. Virtual Reality decouples training from the physical equipment and transfers it from live production into a risk-free learning environment. This prevents risks such as the release of contamination and significantly reduces training costs, e.g. by reducing machine downtime or by relieving training staff. Innerspace Cleanroom Behavior Trainings aim at the continuous training of correct behavior in cleanrooms, in incidents and dangerous situations. The standardized training procedures follow guidelines and SOPs and thus guarantee a consistently high level of training quality. In virtual reality, operators train correct cleanroom behavior without risk, safely and sustainably.

5. LITERATURE

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