

## **VIRT – factory trainer project. A generic productive process to train persons with disabilities**

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### **ABSTRACT**

The production of a desktop VR package to be used by trainers and educators of mentally disabled subjects who seek employment in sheltered factories has been the goal of an EC funded project named VIRT. Three virtual training environments featuring a warehouse, a workshop and an office allow the trainees to practice with typical tasks such as the assembling and the handling of materials and goods. The virtual environments are flexible and can be easily changed to create variants of the basic tasks or to change their level of complexity. The warehouse and the workshop have been extensively tested by 20 disabled workers who had no previous exposure to VR and who worked under close supervision in two Italian sheltered factories during the late period of development. Every trainee spent 96 hours practising on the VIRT-Factory Trainer environments. This activity greatly contributed to the refinement of the product and to the collection of data concerning issues such as learning of procedures and tasks, adaptation to the interaction devices and system responses, and transfer of skills. Learning was apparent even in subjects with rather severe mental insufficiency. Initial difficulties with the interaction devices were greatly diminished after a few weeks of training in all subjects. There is also initial evidence from group analyses that transfer of skills to analogous real tasks may occur. Tutors reported an increase in motivation for work in all participants, which did not change with time. It is concluded that desktop VR training can be proposed to assist the training of mentally disabled workers and that it may produce both specific and unspecific favourable effects. The package is now being distributed to interested institutions and professionals for an additional extended assessment.

### **1. INTRODUCTION**

The demonstration of the educational and training potentials of Virtual Reality to the employers of mentally disabled workers has been the goal of an international project funded by the Horizon - Employment Initiative EC programme and recently terminated. The project named VIRT (for Virtual Reality Training) was approved on winter 1997 by the Italian Ministry of Labour and Social Affairs and was led by CIRAH, a dynamic non-profit association based in Milan supporting initiatives for the disables who are eligible for a job application. VR teams of the Fondazione Don Gnocchi (FDG, Italy) and the University of East London (UEL, UK) participated in the VIRT consortium and were responsible for the research and development activities. National co-operatives (IL MELOGRANO and CSLS from Italy) and national associations from Spain (FEPROAMI) and France (UNAPEI) participated as testing sites providing educators and trainees and carrying out an intensive training and assessment activity. Third Dimension Ltd. (UK) produced the software.

## 2. AIMS AND RATIONALE

Virtual Training Environments (VTEs) can be viewed as tools to assist people in carrying out tasks by providing information and feedback, for example, as a means of executing information-support activities. Perhaps the greatest potential of VE applications for manufacturing is in the area of training, because training is a component of all of manufacturing activities (Wilson et al., 1995). The application of VEs to manufacturing activities is an emerging area but surprisingly, no products have been designed specifically for the disabled workers. This may be because the training of disabled people requires specific knowledge and lies at the interface between education and rehabilitation.

Subjects with a mental disability have limited access to the training tools based on the latest affordable technologies which, on the other hand, are becoming more and more available to non-disabled in educational, training and work places. This represents a critical issue as far as equal access to resources for both disabled and their tutors are concerned and will inevitably produce discrimination if educators, trainers and employers of the disabled are denied the opportunity to participate in the development of specific applications for their workers.

### 2.1 Aims

1) To assess whether low-cost VR technology is suitable to develop models that will supplement and improve current training procedures for subjects whose mental impairments do not totally preclude their integration in a productive activity; 2) to make educators, trainers and sensible employers aware of the potential of VR and make them responsible for a number of critical choices concerning the development, the testing and the systematic use of the new training tool; 3) to assess in the broadest possible way the impact of VR on the disabled and their working environment, 4) to verify whether any transfer of skills from VR to real job activities may occur.

### 2.2 Milestones

We started from an analysis of the training curriculum and work experiences currently offered to employable mental disabled in the participating countries. It emerged that the variety of working experiences they are exposed to is insufficient to make the trainees aware of their role in a productive process and, more broadly, in a working organisation. We concluded that a flexible tool to simulate a wider range of working tasks than those available would have a precise role in the training curriculum of disabled. We anticipated it would have served to broaden their working experience, to foster their decisional autonomy, and to be more aware of their skills. More specifically, it would have been an additional way to interact with tutors and workmates, to share experiences with them, to get reliable feedback, to learn difficult attitudes such as self-monitoring and self-correction through exercise by trial-and-error, free of personal and material risks. This basic philosophy has already inspired other valuable educational applications devoted to increase independent life skills of the disabled (Brown et al., 1997). We then drafted and discussed possible VR scenarios and the tasks to be simulated. Because of the variety of the manufacturing activities carried out in the participating co-operatives and the need to produce a universally acceptable training tool, it was decided to simulate a generic productive process and to split it into 3 independent modules depicting a warehouse, a workshop and an office according to the topological specificity of most training and working sites. The training has been organised around principal tasks and their variants within each VTE. A special effort has been made to provide the product with the wider possible capability to personalise the training, to mimic real job training and insure that the nature of the relationship between the trainer and the trainee be maintained. For example, it was decided to combine video clips to the VR scenarios to provide additional access to instructions and to examples of real tasks sequences, and also to ease the translation of text outputs. It was finally decided to implement the product under a widely available VR platform to maximise its diffusion, and an experienced developer was appointed. A rather intensive iterative developing-testing and refining process started in late autumn 1998 which involved the R&D teams. Deliverables suitable for extended testing have been available since early summer 1999.

A substantial effort has been also devoted to the formal training of the tutors selected by the employers among professional educators, workers and volunteers with previous experience with mentally impaired subjects. A 36 hours intensive course has been organised at FDG spanning all relevant aspects of VR technology devoted to training and education, and to all aspects of the project. Specifically, the tutors were taught how to handle the system components and how to configure the VTEs. The system response to interaction has been the subject of discussion, as it was felt that standard options such as Superscape standard navigation bars were not adequate to meet the users' cognitive and visuomotor abilities. It was then discussed how to organise the intensive training with VR and how to merge it with the trainees' daily activities at workplace. The trainers' role was to configure each VTE and select the appropriate training schedule and

methodology to make the trainees' approach to VR as smooth as possible. Tutors' responsibility was also to take notes and write summary reports at the end of each session and training period.

Two complete multimedia workstations based on Pentium II 400 MHz processors were delivered at each participant site in early summer 1999. An advanced version of software was installed and the system was then introduced to the trainees and their workmates. Desktop VR demos were used for an average of two weeks to practice with the interaction devices.

### 3. METHODS

#### 3.1 Participants

A group of 30 disabled workers (20 in the Italian and 10 in the French and Spanish training sites), participated in the project. All participants had learning disabilities, and matched local criteria for employability in sheltered factories. The training phase spanned an 8 months period between June 1999 and February 2000 in the Italian sites and about one month in the other two sites. Eight senior tutors recruited among staff members (3 in each of the two Italian training sites and one in each of the remaining two European sites) volunteered for the study. Each Italian tutor spent an average of 450 hours teaching VR to trainees, preparing the daily sessions, data recording and managing all sorts of problems in close collaboration with the R&D teams.

#### 3.2 Product development

The 3 VTEs were developed one after the other and submitted to an iterative test-and-refine procedure before they were sent out to serve as experimental training tools. The contribution of the two Italian sites was essential to bring the products at the actual level of development. They worked on a total of 7 successive releases of the software, while the other European testing sites worked mainly on the final release. The VIRT-Factory Trainer package was developed under the latest Superscape VRT 5.6 for Windows. Disables interacted with the VTEs by means of a 2 button mouse (to select objects) and a 2-axis standard joystick (to navigate the VTEs). Specific "dlls" were written to improve the calibration and adapt the response of the joystick to the disables' limits and automatic zooming options were implemented to ease their approach to the smaller virtual objects. Instructions were given orally by the trainers, but textual hints were also optionally available to help on the more complex tasks.

*3.2.1 Warehouse.* This VTE is organised around two "poles of attraction": a set of shelves and a weighing platform located at opposite sites of a large room, which includes other active objects such as a trolley and a conveyor belt. The Warehouse was intended as the entry-level application to acquaint users with the interaction devices and system responses. It requires users to understand simple instructions such as "pick up all the large green boxes on the shelves and put them on the trolley", explore the environment, select objects by clicking on them and, sometimes, move them from one location to another. A number of conditional requirements can be introduced to make the tasks more complex. For example, the selection of objects stocked in the warehouse can be made contingent on several features, such as the colour, shape and size of the envelopes, the position of the boxes on the shelves and their weight - which may be directly checked on the weighting platform. Variants of a given task can be produced by changing features at any session to prevent the user getting bored if asked to repeat the same basic activity many times. The system can be set to provide auditory feedback for any errors, to store time taken, number of hits and failures, specifics of the task carried out, and to track any moves made inside the VE. Time limits can be also introduced.

*3.2.2 Workshop.* This VTE is also organised around two "attraction poles" at the opposite sites of a large room to force navigation back and forth. The workbench, where most of the activity takes place, faces a "painting oven" and an incoming conveyor belt. The application is designed to simulate the assembly of a torch starting from its basic components. Some of them must be processed and refined (e.g. painted, cut or soldered) before they can actually be used, others need to be checked because they can be faulty (e.g. batteries), others are ready to be assembled (e.g. a lens). The user must ensure that all the materials needed are available at the beginning of the job; if not, he/she must retrieve them from containers located on the workbench or from the conveyor belt. The task can be as simple as checking the charge of the batteries or as complex as carrying out the whole assembly involving up to 39 different actions to be performed in the right sequence. The final product is a torch that lights up when the switch is clicked on. As opposed to the warehouse tasks, there is no immediate feedback for errors, but textual hints can be activated to remind the user what has been done and what must be done next. This was decided in order to mimic as closely as possible what happens in real conditions, where assembling goods are practised under a tutor's supervision and errors may be only be detected when a functional check is performed. Time limits can be introduced.

*3.2.3 Office.* The last VTE will be only briefly described here as the project came to an end before it could be tested “on the field”. It was meant to be the last and the cognitively more demanding among the VIRT VTEs. It includes two functional conveyor belts, incoming and outgoing parcels and a virtual computer to deal with orders of materials, printing of labels for outgoing parcels and lists of incoming goods to be stocked in the warehouse. Though icons can replace most of the text, the users must possess simple arithmetic and reading skills. As with the other modules, a configuration file allows the tutor to set levels of difficulty and to introduce time limits for the training sessions.

### *3.3 Training procedures*

Every trainee in the Italian testing sites spent a total of 96 hours working on the VTEs. The activities were usually organised as daily sessions of 45 min. to 1 hour each, under close supervision. Virtual environments, tasks, pass and fail criteria were set to provide incremental levels of difficulty. Tasks in the warehouse and in the workshop comprised 13 and 12 incremental levels of difficulty, respectively, each one with several variants. The first four months of training were spent on the Warehouse VTE. Easy tasks in the warehouse were those requiring only one type of activity without time limits (e.g. selecting items on shelves according to one feature); difficult tasks were those requiring more actions with time limits (selecting, moving, weighing items according to several features). Nine of the warehouse tasks did not have time limits and four were time-limited. Levels 1 to 6 were considered easy tasks (e.g. find objects), levels 7 to 9 were intermediate (finding objects sharing several features), levels 10 to 13 were difficult. The following four months of training were spent on the WorkshopVTE. Easy tasks in the workshop required completion of only one or a few assembly steps without time limits, while the most difficult task required the completion of the entire assembly within time limits. On both VTEs, passing to a higher level was allowed after three consecutive hits. The Office VTE reached full development, but could not be tested on site before the project deadline.

Training activities were preceded by testing on a set of real tasks mimicking those in the VTEs. The same real tasks were repeated at the end of each training period (about 4 months) to assess transfer of skills.

### *3.4 Data recording*

As we were interested in collecting information from various perspectives, we analysed the data which was automatically stored on files by the system, classified errors and tutors’ interventions during the training sessions, and tried to get free reporting as possible from the trainees, their tutors, and from people not directly involved with the training itself such as parents, friends, workmates and other staff members at the work sites. Accordingly, data concerning feasibility, acceptance, side effects, impact on psychological and work-organisation factors, ways of interaction, transfer of learning, perception of usefulness and efficacy have been obtained in the form of written reports or numerical data.

## **4. RESULTS**

### *4.1 The VIRT-Factory Trainer package*

The main product of the VIRT project is the set of 3 virtual training environments which have passed the test-and-refine phases. The package is completed by an instruction manual, a set of configuration files to assist the training, questionnaires and rating scales for feedback information. The Italian version has been distributed to more than 60 potential user sites among those who have expressed their interest. The recipients have agreed to use the software to train disabled workers according to the aims of the project and to provide feedback to the distributors after 6 months of utilisation.

### *4.2 Results of the experimental training & refinement period*

This section deals with data collected from 20 trainees working in the Italian testing sites on the warehouse and workshop modules. The main characteristics of the participants are listed in Table 1. There were 2 trainees with rather severe mental retardation, no reading and counting ability, 5 trainees with intermediate mental retardation and no reading, but some counting ability, and 13 trainees with mild mental retardation who were able to read and count up to 100. Only one subject was slightly motor impaired. Subjects with severe sensory-motor deficits, epilepsy or psychosis were not included. None of the trainees had previous knowledge of standard PC applications nor was exposed to VR; four of them, however, were using simple PC videogames at home. None of the trainees dropped out of training, but the individual number of training sessions varied somewhat due to unrelated causes (some trainees had transient mild illnesses, others took a full month off in the summertime, etc.).

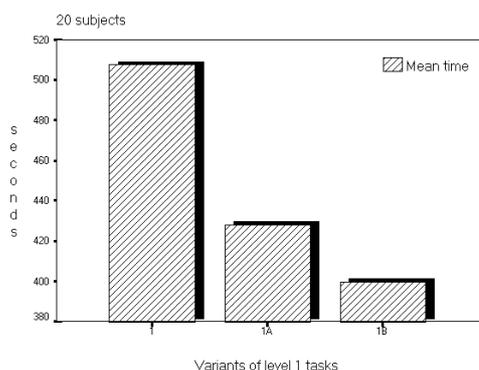
**Table 1. Participants' characteristics.**

Test site	Sex	Age	Handedness	% disability	Diagnosis *	Reading	Counting
1	F	35	Right	100	Severe mental insufficiency	No	No
1	M	23	Right	70	Mielomeningocele, mild mental insufficiency	Yes	Simple arithmetics
1	M	29	Left	75	Borderline personality, mild mental insufficiency	No	Simple arithmetics
1	F	19	Right	50	Mild mental insufficiency	Yes	Up to 100
1	F	31	Right	70	Moderate mental insufficiency	No	Up to 100
1	M	23	Right	75	Moderate mental insufficiency	Yes	Up to 100
1	F	20	Right	100	Tetraparesis, mild mental insufficiency	Yes	Simple arithmetics
1	F	28	Right	45	Hypoacusis, mild mental insufficiency	Yes	Simple arithmetics
1	M	27	Right	70	Moderate mental insufficiency	Yes	Simple arithmetics
1	M	24	Right	46	Borderline personality, mild mental insufficiency	Yes	Simple arithmetics
2	M	28	Right	100	Down's syndrome, mild mental insufficiency	Yes	Simple arithmetics
2	M	21	Right	100	X Fragile syndrome, mild mental insufficiency	Yes	Up to 100
2	M	26	Right	100	X Fragile syndrome, mild mental insufficiency	No	No
2	F	23	Right	100	Down's syndrome, mild mental insufficiency	Yes	Simple arithmetics
2	M	19	Right	100	Down's syndrome, moderate mental insufficiency	Yes	Simple arithmetics
2	M	26	Right	70	Mild mental insufficiency	Yes	Simple arithmetics
2	M	30	Left	65	Mild mental insufficiency	Yes	Up to 100
2	M	28	Right	100	Down's syndrome, moderate mental insufficiency	No	No
2	M	26	Left	100	Moderate mental insufficiency	No	No
2	M	30	Right	100	Down's syndrome, mild mental insufficiency	Yes	Simple arithmetics

\* Clinical records were not always available for this project

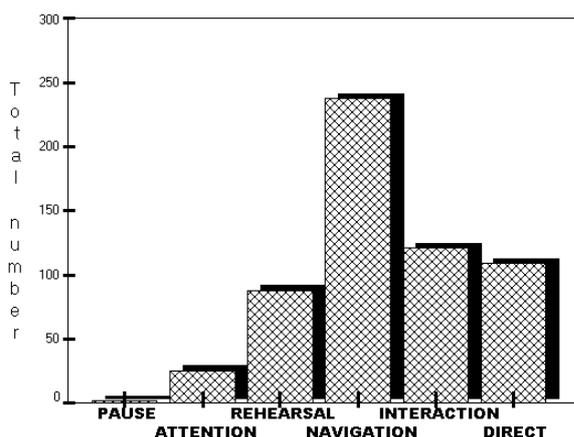
*4.2.1. Training with the virtual Warehouse.* Subjects took an average of 102 training sessions (45 to 223) carrying out the warehouse tasks. The lowest training level achieved was 8 (1 trainee), the highest was 13 (14 trainees). A number of performance measures were used to document the pattern of learning, but the number of sessions to achieve a change in level seemed the most comprehensive. The group's average performance improved as a function of repetitions (time of training) and of the level of difficulty of the tasks; e.g. repetition across similar tasks improved mean performance while the change to more complex tasks produced a transient drop in performance measures, which then began to improve again with practice. For example, trainees took on average 12 sessions to change from level 4 to 5 (a time-limited task), but only 7 sessions to pass from level 7 to 8. As predicted, time-limited tasks were judged as more difficult and produced more distress to trainees than time-free tasks, in spite of the fact that time limits were set on the basis of individual performances. Two of the trainees refused to take time-limited tasks.

Summer breaks caused some trainees a transient drop of performance when they came back on training. At the beginning of the training almost all trainees reported some difficulty dealing with the interaction devices and system responses, but only 2 trainees still needed some tutor's support with navigation at the end of the fourth month. The change of performance on easy tasks documents the learning of interaction skills (Fig. 1).



**Figure 1.** Learning with the firstVTE. Total group mean time to complete variants of level 1 tasks in the virtual warehouse.

Similarly, seven trainees reported some anxiety at the beginning, but only one still needed reassurance after four months of training. The interventions were classified into 6 types based on tutors' reports: 1, requests for a pause; 2, keeping subjects concentrated on the task; 3, minor suggestions or rehearsal of instructions; 4, assistance with navigation problems; 5, assistance with interaction problems; 6, direct solution of the problems. The majority of interventions belonged to type 4 whereas, surprisingly, very few type 1 and 2 interventions were reported (Fig. 2).



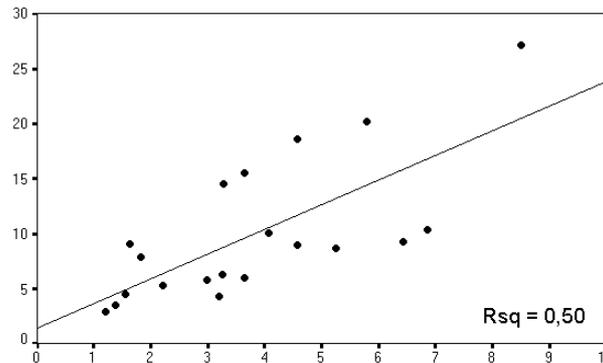
**Figure 2.** Tutors' interventions during training with the first VTE.

The correlation between a summary performance measure (based on the maximum level achieved, the number of training sessions taken and the mean time to complete a session) and clinical disability scores was significant (Spearman's  $r = -.61$ ;  $p = .004$ ) and in the expected direction (greater disability = lower performance). However, even the more severely disabled trainees were able to show some improvement over time.

**4.2.2. Transfer of learning: Warehouse tasks.** This issue has been addressed to only a preliminary level. In fact, no control groups were used and tutors served as raters, as we limited ourselves to an initial assessment of procedures to be used in future studies. The transfer of training was tested by asking subjects to retrieve items from the real warehouses according to precise indications. The tasks were repeated twice, once before and once after the training with the virtual warehouse. The number of items correctly retrieved and the time taken to complete the task were used as measures, as they may not be much affected by subjective factors. As a group, trainees were significantly faster (mean  $345 \pm 156$  sec. vs  $272 \pm 236$  sec.; Wilcoxon signed rank test  $Z = -2.11$   $p = .03$ ) and retrieved more items (mean  $5.6 \pm 1.8$  vs  $6.1 \pm 1.8$ ;  $Z = -2.10$   $p = .03$ ) after the virtual training. It must be noted that at least 4 months elapsed between the test and the retest.

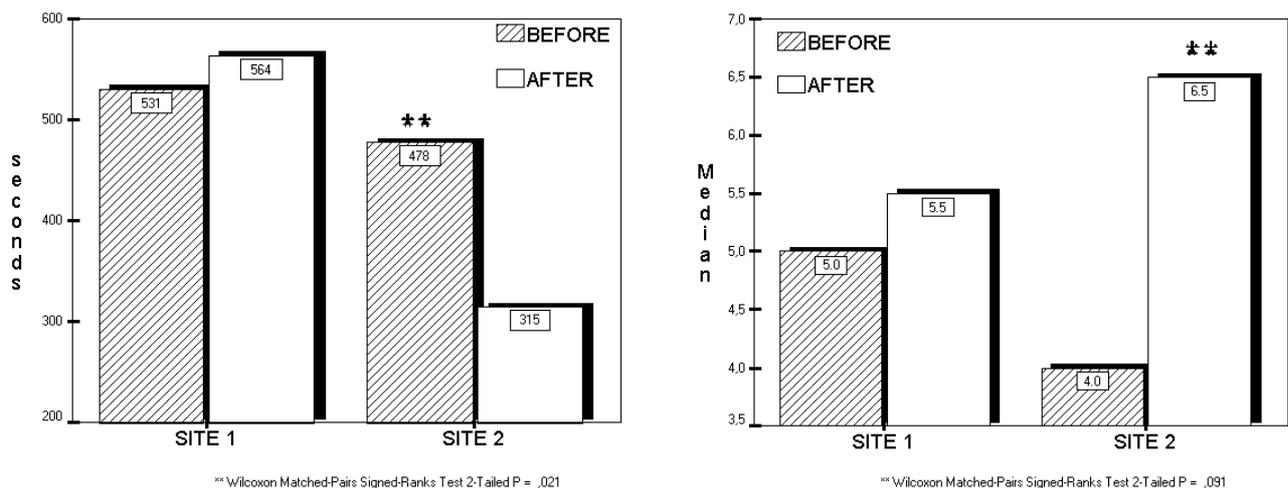
**4.2.3. Training with the virtual Workshop.** Trainees took an average of 78 training sessions (range = 31 to 149) carrying out the workshop tasks. The lowest training level achieved was the 3<sup>rd</sup> (2 trainees), the highest was the 12<sup>th</sup> (2 trainees); the majority of the remaining subjects (n.11) could reach the 9<sup>th</sup> level. Once again, the trainees judged time-limited tasks as more difficult than time-free tasks. Unlike the warehouse tasks, time

measures were not particularly useful as performance indices here, as more difficult levels also implied more activities to complete. No major difficulties with the interaction and navigation tasks were reported, as subjects were already used to them. Most of tutors' interventions were aimed to remind subjects what they should do next. In general, trainees liked the workshop environment and the assembly tasks more than the warehouse tasks. In a few cases, their motivation and performance was unexpectedly good. The linear correlation between individual summary performance measures in the two virtual learning environments was, however, statistically significant (Fig. 3).



**Figure 3.** Correlation between individual summary performance measures on the two VTEs. 20 subjects. VTE 1 on abscissa, VTE 2 on ordinate.

4.2.2. *Transfer of learning: assembly task.* The transfer of training was tested by asking each trainee to assemble an exact real replica of the virtual torch without instructions. The test was repeated twice, once before and once after the virtual training. The number of parts correctly assembled and the time taken to complete the task were used as measures. Again, subjects were faster (mean  $504 \pm 251$  sec. vs  $439 \pm 224$  sec.) and put together more parts correctly (mean  $4.5 \pm 1.9$  vs  $4.9 \pm 2.6$ ), but the differences did not reach statistical significance. The retest outcomes were different in the two testing sites, however, as separate analyses showed a significant improvement in one and no change in the other (Fig. 4).



**Figure 4.** Transfer of training with the second VTE. Left: mean times to complete the assembly of a real torch before and after the virtual training. Right: number of torch components correctly assembled.

#### 4.3 Additional results

The presence of unwanted or side-effects among participants was specifically investigated after each VR session, but no such events occurred. Tutors' notes and reports were important to interpret data stored by the system as times and number of hits and misses. Tutors reported on 92.3% of 2080 training sessions with the Warehouse and 90% of 1570 sessions with the Workshop VTEs. Overall, adequate notes were obtained 84%

of the times. Notes were critical to understand the nature of problems, difficulties and errors made by the trainees on 37.5% of failed tasks and on 11.8% of passed tasks. Non critical, but useful, notes were available on an additional 12.8% of the training sessions. Incomplete or ambiguous notes were present in 7.2 % of the cases. Tutors reported they made critical interventions on 6.5% of the sessions to solve trainees' difficulties. Technical faults occurred on 2.4% of the training sessions, but the work could be resumed within a few minutes most of the times. In their final reports, tutors stated they could not have anticipated such a significant mean improvement in their trainees' ability to work with the VTEs and - more generally - with a PC. The employers judged the impact of the VR training on workplace organisation and routines as tolerable. Most of the trainees reported enthusiastic feelings and showed high motivation which did not drop off during the training. They also showed a greater positive attitude during ordinary work tasks. Both parents and educators reported the trainees' self-esteem was improved because of the opportunity that they had to use a PC to work with. Some trainees have repeatedly shown their ability to interact with virtual learning environments during public shows and demonstrations of the VIRT-Factory Trainer package. Because of this, it was decided that disabled workers not originally included in the training would be given the same opportunity to practice with VR after the official end of the project. Following their participation to the VIRT project, some of the trainees began to use a PC at home.

## 5. CONCLUSIONS

The research and development activities of the VIRT project have been successfully completed within the 2-years period allocated. As a result, a set of VTEs is now available to train mentally disabled who are employed or who seek employment in sheltered factories, and to make tutors and employers aware of the potential value of VR as a new training tool. To our knowledge, this has no antecedents as far as VR applications for disabled are concerned. The VTEs embed many of the up-to-date desktop VR enhancements, run on standard hardware under Windows '95-'98 environments, are easy to configure and fully documented. Furthermore, they produce multiple outputs which may serve to document trainees' learning. The product is now being distributed at no cost to all interested parties in order to make as many professionals aware of it and to complete the expanded testing phase. The product on distribution has passed an 8 months testing-and-refinement phase in the hands of 20 disabled trainees and 6 tutors in Italy and of an additional 10 trainees in two other European countries. Feedback from the latter is expected within the next two months. This intensive activity produced a number of results, the most basic of which is that the applications are adequate for a supervised training of mentally disabled subjects who meet criteria of employability. More specifically, we have been able to document that:

- practice reduced initial anxiety levels and difficulties with standard interaction devices;
- mean performance improved during training, though time-limited tasks were perceived as more difficult and stressful;
- performance on the virtual tasks reflected to some extent the individual levels of disability and learning impairment, but even the more severely impaired subjects were able to tackle the easier tasks and learn from practice;
- motivation was not lost during repeated exposure to VR; some trainees showed transient "holidays" effects;
- there is preliminary evidence that some transfer of learning occurs from VR to analogous real tasks.

This evidence, however, is still tentative as no control groups have been used so far, and differences in tutors' attitude during training may have influenced the transfer of learning in the case of the assembly task. Results seem, nonetheless, promising enough to warrant further formal appraisal of this issue, as learning disabled were already shown to be able to transfer VR-trained skills into real life situations (Cobb et al., 1998).

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