

OPTIMIZING THE TRANSFER BETWEEN GENERIC AND TYPE-SPECIFIC SIMULATORS IN INDIVIDUAL AND TEAM TRAINING

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Abstract

Nowadays, many individual and team training trajectories include multiple simulators and training environments that differ in functionality, appearance and interface from each other and from the working environment. The use of different training environments within one training trajectory requires from students the transfer of knowledge and skills learned from one learning situation to a 'new' (learning or working) situation. This paper discusses a research study aimed at identifying transfer problems between generic and type-specific simulators for the RNLN Operational School. Using a combination of qualitative and experimental research methods, this study shows that there are many factors contributing to the large relapse students experience when moving from generic to type-specific simulators. Recommendations include, amongst others, a change in training strategy and a different design and organization of the training trajectory.

Biographical sketch

Michael Bots is a research scientist working within the department of Training & Instruction at TNO Human Factors. He is involved in many research projects directed toward improving training effectiveness of complex training environments. His professional interests include the training of teams (in particular cross-training), transfer of training, cognitive modeling and the application of simulators and other advanced technologies for training purposes. He holds a M.Sc. degree in Educational Science of the University of Nijmegen in The Netherlands and is currently working towards his doctoral thesis 'Tailored team training'.

Alma Schaafstal studied Cognitive Psychology and Philosophy at the University of Groningen, The Netherlands, and the University of Manchester, UK. She wrote her dissertation (1991) on expert-novice differences in diagnostic skill in papermaking. In 1985-1986 she spent a year as a visiting scientist at Carnegie Mellon University, Pittsburgh, PA. She has been with TNO, the Dutch Organization for Applied Scientific Research since 1986, and since 1990 she is affiliated with TNO Human Factors, specializing in training complex skills in military environments, with a strong focus on team training. As part of an exchange program of the US and The Netherlands, she is currently with the Naval Air Warfare Center Training Systems Division Orlando, FL, focusing on training teams with simulated teammates.

Optimizing the transfer between generic and type-specific simulators in individual and team training

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INTRODUCTION

Many training programs rely on the use of multiple simulators and other training environments in order to improve the learning results and transfer to the working situation. This may result in a tendency to consider each new simulator as an isolated training device without taking other parts or aspects of the training into account. Neglecting the relationship between different (aspects of) training situations could result in the occurrence of problems in transferring knowledge and skills from one training situation to the next. Transfer of learning in this context refers to the degree to which prior learned knowledge and skills influence the use of these knowledge and skills in new learning or working situations (Cormier & Hagman, 1987a/b).

When using multiple simulators and training environments within one training trajectory, students have to transfer the knowledge and skills learned in one training environment to the next and finally transfer their knowledge and skill to the working situation. In some cases this transfer process happens almost automatically but in most cases this requires special attention in order to eliminate or minimize potential transfer barriers and to stimulate transfer of learning to occur. Many theories exist about how to improve this transfer process, some of which emphasize the importance of common elements in the learning and transfer situation (all related to the original 'identical elements' theory of Thorndike & Woodworth; in Holding, 1991) whereas other theories emphasize the strategies that can be used to improve the abilities of the learner to store and retrieve information and to generalize the learned knowledge and skills to the transfer situation. Simons (1990) provides an excellent overview of these latter theories aimed at improving the transfer ability of the learner.

Although research has resulted in more knowledge about the effect of certain factors on transfer of learning, there is a clear need to integrate these findings and different theories in order to gain a deeper, more detailed understanding of how to improve the transfer of learning in the workplace.

This paper describes an applied research study aimed at improving the transfer of learning between different simulators used in a training trajectory for the Operational School of the Royal Netherlands Navy (RNLN) and will help to understand the requirements for transfer of learning to occur.

The RNLN Operational School

Within the Operational School of the Royal Netherlands Navy a variety of simulators is deployed in both individual and team training trajectories, amongst others aimed at the training of operators working in the Command Information Center (CIC) of RNLN frigates. The simulators used in the beginning of this training trajectory, for the training of individual task-work skills, are generic in nature and have a different (more simplified) interface compared with the systems on board. These generic simulators are used for part-task training purposes with a focus on the learning of basic operating skills and voice procedures. An example of these kind of generic simulators is the Radar Picture Compilation Trainer (RBOT). As the training trajectory proceeds, the focus shifts gradually from individual mainly task-work related training towards team training and from part-task training towards whole-task training. The simulators used at this latter stage are type-specific in nature, which means that their interface and working environment closely resemble the systems on board of a RNLN frigate. Examples of these type-specific and team-oriented simulators are the M-frigate and S-frigate trainer.

Training trajectory of operators

In the present study the focus is on the training trajectory of operators responsible, amongst others, for picture compilation tasks. The training trajectory consists of three or four modules, depending on the specialization of the operator in a specific warfare domain and the type of frigate to which the operator will be assigned.

The general organization of the training trajectory in modules is based on a division in three levels:

1. *Generic picture compilation*; on the first level students are trained in the basic elements of picture compilation in general (independent of the domain or type of frigate). This module consists of both theory and practice using a generic picture compilation trainer.
2. *Domain-specific picture compilation*; on the second level the first specialization occurs based on the operator position (air picture compiler or subsurface picture compiler) the student is going to perform in the future. The task of surface picture compilation is integrated in (the training of) both operator positions. This specialization is primarily based on the needs of the Navy and, whenever possible, on the preferences of the students. The modules are theoretical in nature and are in principle independent of the type of frigate the operator is going to work on.
3. *Type-specific picture compilation (M-frigate or S-frigate)*; on the third level the students are trained for performing a specific operator position at the M-frigate or S-frigate. The task of surface picture compilation remains an integral part of the training in all modules. The modules consist of both theory and practice on the type-specific team trainers.

In the modules mentioned above, students are trained using both theoretical and more practice oriented lessons. The theoretical lessons are focussed on acquiring knowledge about the equipment, organization and task performance on board whereas the practice lessons are focussed on the training of specific skills required to operate the work station and to cooperate with other team members. In order to train these practical skills, various simulators and training environments are used, amongst others the generic picture compilation trainer and the type-specific team trainers, which have been mentioned above. These trainers will be discussed in more detail in the next section.

Generic and type-specific trainers

In this section the appearance and operational characteristics of the various trainers will be discussed, beginning with the generic picture compilation trainer.

The radar picture compilation trainer (RBOT) offers a generic, i.e. independent of the type of frigate, training environment in which students can learn and practice their skills regarding (elementary) picture compilation and all kinds of operational and communication procedures. For this purpose, the trainer consists of twelve identical operator workstations, which can be

used stand-alone, or in a networked organization. The operator workstations have in principle the same functionalities as the work stations on board but are somewhat simplified in order to enhance learning and generalizability to the different frigates. Important differences in this respect include the more simplified appearance and interface of the workstations (especially when compared to the interface of workstations on the M-frigate) and in some cases different operating procedures are used.

The type-specific team trainers are training environments simulating the situation of a CIC on board of a RNLN M-frigate or S-frigate. Within these trainers students learn how to operate the frigate-specific workstations and how to cooperate with other team members (according to all kinds of specific communication and operational procedures). In the next section, the characteristics of the (work stations in the) S-frigate and M-frigate trainer will be briefly described.

The S-frigate trainer consists of seven work stations for the operator team and three work stations for the command team. The operator work station in the S-frigate trainer is in principle identical to the operator work station in the CIC of a S-frigate. Although the functionalities are the same as in the generic trainer, the interface, operating procedures and system capabilities are more complex. On top of that, an increasing number of distractors is present, such as noise on communication channels and clutter on the radar screen. Another important characteristic of the S-frigate trainer is the darkened environment, which has important implications for the cooperation (especially the nonverbal communication) between team members.

The M-frigate trainer on the other hand consists of sixteen multifunctional workstations, which are identical to the workstations in the CIC of a M-frigate. As with the S-frigate trainer, the most important differences with the work stations in the generic trainer are the increasing complexity of the interface, the operating procedures and the system capabilities and, on top of that, an increasing number of distracting factors. A major difference between the S-frigate trainer and the M-frigate trainer is that the M-frigate (trainer) is not darkened.

Future trainers

Because of the limited capacity of the type-specific trainers for accommodating large groups of students and the high costs involved in buying and maintaining type-specific trainers, the emerging trend within the Royal Netherlands Navy is to use generic simulators (like the RBOT) more often in the future for training

basic operating skills. The underlying training philosophy is to learn and automate the instrumental and procedural knowledge in the generic trainers, in order to be able to focus explicitly in the type-specific trainers on the training of operational and team skills.

Although this training philosophy seems very appealing, there are still some challenges that need to be faced in order to optimize the learning process and outcomes during the whole training trajectory. An important challenge in this respect is linked to the transfer problems occurring in the transition from generic to type-specific simulators. The practice shows that the knowledge and skills learned in the generic simulator do not transfer automatically to the type-specific simulator leading to an apparent drop in performance and learning progress. The question is what causes these transfer problems and how this situation can be improved upon.

In order to find an answer to this question a research project was started aimed at formulating recommendations for optimizing the transfer of learning between generic simulators and frigate type-specific simulators, focussing on the following issues:

- Interface design of generic part-task simulators
- Optimization of training trajectories
- Adaptation of training strategies
- Organizational implementation of training

These issues reflect the notion that the current transfer problem can be caused and influenced by a variety of aspects on different areas, all interacting with each other and thus requiring an integral problem approach.

METHOD

In order to investigate this integral problem area and enabling a wide range of problem solutions, we believed it to be important to explore a variety of contributing factors from a number of different perspectives. Therefore, the study consisted of four different parts:

1. Functional decomposition of the task of surface picture compilation
2. Training analysis of the different modules
3. Questionnaires on the reaction level of students
4. Comparison of the performance of students in different simulators/trainers

In the next section the different parts will be discussed in further detail.

Research design

1. *Functional decomposition*; the main study started with a functional decomposition of the task of surface picture compilation and how this was implemented in the various simulators. The reason for this detailed analysis was to identify the differences in functionality, operating procedures and interface of the generic and type-specific simulators. Based on NATO and RNLN documents and interviews with instructors, a hierarchical task analysis was performed. Using this analysis the task of surface picture compilation was systematically divided into subtasks, finally resulting on the lowest subtask level in an identification of the procedures and (system) actions required to perform this subtask. Using this functional analysis we were able to acquire an initial understanding of the differences in training and working environment that trigger or prevent transfer of learning to occur.
2. *Training analysis*; to acquire more knowledge about the training context of the transfer between the various trainers, an analysis was performed of the training program. Based on training documentation and observations of instructor and learner activities during theoretical and practical lessons, an analysis was made of the subjects, training approach, training strategy and instructional methods used.
3. *Questionnaires*; in addition to the objective performance comparison (see next section), questionnaires were used to collect the subjective experiences of students on four specific points throughout the whole training trajectory. The students were asked to fill in this questionnaire at the beginning of the first module, at the beginning of the second module (after finishing the scenario in the generic trainer), and at the beginning and at the end of the training period in the type-generic trainer (third module). The questionnaires consisted of a combination of open questions and questions that needed to be answered on a Likert-scale (five-point scale). The goal was to collect information about the personal experiences of students regarding all kind of training and transfer issues. Students were asked to reflect on their learning progress, provide feedback on the training program and formulate expectations about how they were planning to use the learned knowledge and skills in the (next) training or working environment.

4. *Comparison of performance*; to acquire more objective knowledge about the differences in performance that occur as a result of the change in the training environment, a within-subjects comparison was made of the operator performance on identical scenarios at the end of the training period at the generic simulator (first module) and at the beginning and end of the training period on the type-specific simulator (third module). The scenario used was the final exam on the generic trainer, which had been translated to an identical scenario in the various type-specific trainers. At the beginning of the third 'frigate-specific' module, students first received a short training (six one-hour lessons divided over three days) on the different interface and operating procedures of the type-specific trainer, before they were exposed to the same scenario as in the generic trainer. The purpose of this short training period was to prevent the presence of transfer problems caused by lacking system knowledge of the students. The performance of the students participating in these scenarios was video-recorded and analyzed by experienced instructors using predefined observation criteria. The observation criteria were linked to the number of correct and incorrect actions regarding operating the workstation and communicating and coordinating with other team members. These observations enabled us to obtain quantitative indications of the transfer level, and also assisted the analysis of the transfer problems in terms of their possible underlying causes.

Subjects

During the study three groups of students were observed from the beginning of the training trajectory until the end or until the moment that they dropped out. None of the students had prior experience with the domain and the education level of students beginning at the training program varied from preparatory to intermediate vocational education. The total number of students participating in the beginning of the training trajectory was 34 (11 female and 23 male students) but due to illness and dropouts at several moments during the whole training trajectory, this number of participants was significantly reduced. For instance, with regard to the performance observation in the various trainers only 21 (10 female and 11 male) students were included. In this respect, participation in the first (the final exam on generic trainer) and second session (the first session on the type-specific trainer) was considered conditional for being included in the data analysis. After the initial training period in which all students were trained on the generic trainer, the students were assigned (based on the needs of the Royal

Netherlands Navy and secondarily on their own interest) to a specific training trajectory leading to a specific operator position on a M- or S-frigate.

Task

The focus in the present study was on the task of surface picture compilation, which is an integral part of all possible training trajectories for operators. This task requires operators to monitor tracks on a radar screen that need to be investigated in order to identify potential threats to the mission of the frigate. In order to perform this task adequately the operator has to perform the following subtasks:

- Adjust (initial) settings of the work station
- Monitor the radar screen and initiate, track and identify radar tracks
- Collect, interpret and integrate information from multiple information sources
- Coordinate activities and communicate in a timely and efficient manner
- Perform actions within specific procedures such as man overboard and a stopping procedure.

All these subtasks were integrated within the scenario used to observe the performance of students. The scenario consisted of four radar tracks, moving around in an area specifically assigned to a student. These tracks had to be correctly initiated, monitored, reported, and identified. Furthermore, since one of the four tracks moved from one area to another, the students had to coordinate their activities with the other students. Finally the students had to perform a specific procedure at some point during the scenario aimed at updating the actual position of the frigate in the Naval Tactical Data System (NTDS).

Independent variables

Two independent variables were used in the present research study. The first independent variable was the simulation session consisting of three levels: the end of the training period in the generic trainer, and the beginning and the end of the training period in the type-specific trainer. The second independent variable used was the kind of type-specific trainer (M- or S-frigate) the student was assigned to.

Dependent variables

The dependent variables used consisted of the number of correctly performed subtasks (8), the number of correct communication reports (8) and the number of correct system actions while performing the specific procedure (6). Additionally, the nature of incorrect

performed subtasks, communication reports and system actions were judged by instructors.

Data analysis

Within a few weeks after ending the last session in the type-specific trainer, two experienced instructors of the Operational School analyzed the video-recordings of the performance of the students using an observational checklist. The observation criteria were linked to the number of correct and incorrect actions regarding operating the work station and the communication and coordination with other team members. Each instructor was trained in using the checklist during a four-hour training session in which they received an instruction, discussed the observation criteria and were tested on an identical scenario. Although the inter-rater reliability was sufficiently high (Kappa-coefficient 90%), instructors were explicitly instructed to both monitor the performance of a particular student on all three scenarios in order to prevent interpretation differences between instructors.

To reduce the huge amount of data resulting from the different parts and to focus on the core of the research study, the results and discussion section of this paper reports primarily on the differences resulting from the performance comparison. The results of the functional decomposition, training analysis and the questionnaires will be briefly summarized and primarily be discussed to acquire a deeper understanding and explanation of the results found in the 'performance comparison' part of the study.

RESULTS

In the next section the results will be discussed for each part separately, paying special attention to the comparison of performance in the different trainers.

1. Functional decomposition

The functional decomposition of the picture compilation task revealed two important findings. Firstly, it confirmed the assumption that the generic and type-specific trainers share a corresponding functionality. This finding is important since it emphasizes that the transfer problems are triggered by a different implementation of the various functions. Secondly, this difference in implementation is revealed on many aspects such as an increasing number of operations necessary to adjust the (initial) settings in the type-specific trainers, the decreased accessibility of specific system actions to perform basic tasks in the type-specific trainers and the higher complexity in appearance of the radar screen and interface of the work

station in the type-specific trainers (containing more information but increasing the complexity).

2. Training analysis

The analysis of the training program revealed some important findings concerning the focus of attention in training strategy, the training time and organization of the whole training trajectory. Regarding the general training approach and training strategy, a first striking observation is the focus on differences between the generic and type-specific trainers, whereas an approach which is more geared to initially pointing out the commonalities in functionality between trainers may be more helpful in transferring knowledge and skills. The documentation, instruction and exercises in the trainers could be characterized as primarily 'button-oriented' emphasizing the different interface and operating procedures between the generic and type-specific trainers.

The second observation is the difference in training time between the various modules and between the generic and the type-specific trainer. The first module for instance covers a period of 51 days while the modules on the second and third level respectively cover a period of 7-9 and 7-28 days. Similarly, the time to practice (surface) picture compilation in the generic trainer is 56 hours and in the type-specific trainers' 18-24 hours. In addition to the fact that there is less practice time in the more complex training environment, the time lag between the generic and type-specific trainers requires students to retain the learned knowledge and skills for almost two weeks in which they learn all kinds of new knowledge that could interfere with the retention and transfer process.

Finally, regarding the organization of the training trajectory, it can be observed that a lot of ad-hoc changes are made to the training program based on the availability of the trainer. This dependency on the availability of the trainer interferes with the regularity of practice in the trainer causing an increase in workload on some days and sometimes a considerable amount of time between instruction and practice.

3. Questionnaires

The questionnaires show a variety of opinions among students about training issues such as the learning content, pace during lessons, instruction, feedback, learning material and amount of practice. This variety in opinions may illustrate the difficulty of the transfer problem and can be considered as a first important result. Apparently, there is no consistent opinion among all students, possibly due to individual differences of a

wide range. Despite this variety in opinions some trends can be identified. In general the students rate the beginning of the training trajectory as too theoretical in nature. This aversion towards the large amount of theory in the beginning is reflected in a low quality rating of the documentation (a large number of students indicate they do not even read some books assigned to them) and a high number of comments indicating a loss of motivation and interest in the training program

4. Comparison of performance

In order to compare the performance of students in the generic and type-specific trainers, exploratory analyses on the data were performed using MANOVA's. In the next table the results are displayed for each variable group regarding the performance of students in the various trainers (see table 1). The table displays the number of correct actions regarding correct performed subtasks, correct voice reports and correct procedural actions. The maximum number of correct actions on each variable group is displayed between parentheses in the variables column.

Mean performance of students in session 1-3

Variables	Generic Trainer (session 1)	Type-specific Trainer (session 2)	Type-specific Trainer (session 3)
Correct performed subtasks (26 max.)	24.6 (SD 1.7)	12.2 (SD 7.1)	19.9 (3,5)
Voice Reports Correct (26 max.)	25.1 (SD 1.2)	11.5 (SD 6.4)	18.9 (SD 2.9)
Correct procedural actions (15 max.)	13.5 (SD 2.9)	5.2 (SD 4.9)	9.9 (4.1)
Total number of correct actions (67 max.)	63.2 (SD 2.8)	28.9 (SD 13.3)	48.7 (SD 6.1)

Table 1 Mean performance scores (and SD) of students in the generic and type-specific trainers

In general, the results show that students experience a significant relapse in performance at the beginning of their training at the type-specific trainers, compared to their performance in the generic 'radar picture compilation trainer'. This relapse in performance is visible on the number of correct performed subtasks, $F(1,20)=65.62$, $p=0.00$, the number of correct communication reports, $F(1,20)=97.07$, $p=0.00$, and the number of correct operating actions during the specific procedure aimed at updating the actual position of the frigate in the NTDS, $F(1,20)=54.74$, $p=0.00$. The

performance difference between simulation sessions was significant on each of the dependent variables within the reported groups of variables.

In addition to the performance differences associated with the transition from generic to type-specific trainers, there is also a clear learning effect visible during the training period at the type-specific trainer. Although students improved their performance significantly at the end of this training period, this performance still remained significantly below the performance level at the (generic) radar picture compilation trainer. The students improved their performance during the training period at the type-specific trainer on the number of correct performed subtasks, $F(1,20)=21.2$, $p=0.00$, on the number of correct communication reports, $F(1,20)=27.75$, $p=0.00$, and the number of correct operating actions during the specific procedure aimed at updating the actual position of the frigate in the NTDS, $F(1,20)=14.67$, $p=0.00$. This trend was visible with regard to all the dependent variables used.

Another interesting observation is the higher variance in the first session of the type-specific trainer indicating the importance of the adaptive (transfer) capability of individual students. The results displayed in table 1 show that as the mean performance of the student increases during training at the type-specific trainer, the amount of variance decreases. In addition to performance improvement, the training at the type-specific trainer apparently leads also to more uniformity between the performance of students.

Furthermore, the results of secondary analyses showed no interaction effect between the type of trainer (M- or S-frigate) on the one hand and the simulation session (generic versus type-specific) on the other hand. However, there appeared to be a main effect of the type of trainer. Students moving from the generic trainer to the S-frigate specific trainer performed better than students moving from the generic trainer to the M-frigate trainer did. This effect was significant on the number of correct performed subtasks, $F(1,19)=5.98$, $p=0.02$ and on the number of correct operating actions during the specific procedure aimed at updating the actual position of the frigate in the NTDS, $F(1,19)=13.51$, $p=0.00$.

However, as the next figure illustrates (see figure 1, which displays the subtotal of correct performed subtasks and voice reports in the various simulator sessions), this difference is already present in the generic trainer, $F(1,19)=5.88$, $p=0.03$. Therefore, other reasons than the type of trainer must explain this difference in performance. However, secondary

analyses performed using gender, age and prior education level showed no effect. Future analyses, focussing amongst others on motivational issues and specific cognitive skills, should bring more clarity in this issue.

Performance differences between the M-frigate and S-frigate trainer

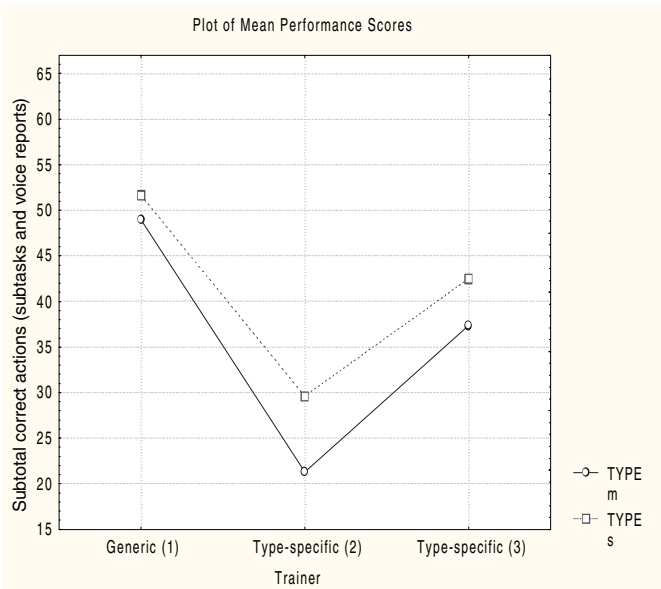


Figure 1 Mean performance at multiple sessions in the generic and type-specific trainers (M- or S-frigate).

DISCUSSION

In general the results show a significant relapse in performance from students moving from the generic to the type-specific trainers indicating the presence of important transfer problems. The fact that this relapse in performance could be observed on every dependent variable (on the operational as well as on the communication level), shows that this is a consistent problem, causing even performance aspects that seem independent of the training environment, such as the contents and procedure of voice reports, to experience a significant relapse. The functional decomposition analysis shows that various differences in interface, accessibility and number and complexity of operations contribute to triggering this transfer problem.

A question to pose would be whether these results could likely be attributed to interpolated activity and the passage of time between the post-test on the generic simulator and the initial test on the type-specific trainer. One way to investigate this issue would have been to add a control group to our design, which, instead of

being tested on the type-specific trainer, would have been tested on the generic trainer. However, for practical reasons, this turned out to be impossible. The school did not allow us to change the educational practice for the course of this experiment, due to a number of reasonable concerns. On top of that, the interpolated activity was not totally irrelevant to the task at hand.

Consequently, the challenge for the training program, is how to overcome these differences by using the most appropriate training strategies. To understand how to improve the training trajectory one needs to return to the fundamental processes underlying the transfer phenomenon (Bots & Veldhuis, 1998). In order for transfer to occur students have to retain the knowledge and skills learned in the generic trainer (retention process) and translate these to the type-specific trainer (transfer process).

With regard to the present situation, the most important problems seem to originate in the design, strategy and organization of the training trajectory. Firstly the time lag is important between the training periods at the different trainers and between the acquisition of theoretical knowledge and bringing it into practice. This time lag, which is caused structurally by the intermediate module (the theoretic module focussing on domain-specific picture compilation) and incidentally by the non-availability of practice time in the trainer, should be reduced to diminish the problems associated with the retention of knowledge and skills learned in the generic trainer.

Secondly, concerning the translation of acquired knowledge and skills to the new situation (the type-specific trainer), a change in focus of attention seems important. In particular, it seems difficult for students to see the functional equivalence between the various simulators. This problem may reflect a sub-optimal training strategy: the explanation of the interface of the frigate-type specific trainer is largely 'button-oriented' and focuses on differences instead of similarities between the simulators. In the training strategy we propose that students are explicitly made aware of the common functionalities between the trainers. This change in emphasis has important implications for the training documentation and the instruction and feedback of the instructors. For instance the exercises in the training documentation should not only contain information about the consecutive steps that have to be performed and buttons that have to be pressed but should students learn what they are doing and why they are doing it. This should be supported by instruction, feed-forward (in the generic trainer) and feedback (in the type-specific trainer) of the instructors emphasizing

that the functionalities remain the same but the implementation is somewhat different.

In addition to these practical recommendations, more research in the future is necessary to gain a deeper understanding about the specification of (generic) trainers which in combination with the design of the training trajectory lead to optimal learning and transfer results.

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