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Factors Related to Negative Transfer of Training in Safety-Critical Professions: An Interview Study

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ABSTRACT

Literature on transfer of training largely deals with positive transfer. Only few studies exist on negative transfer, and these were often performed in (laboratory) environments with low ecological validity. This study's objective is to identify factors that contribute to negative transfer in safety-critical professions. The primary focus of the study is on aviation, but investigated principles also apply to other domains with high-performing professionals. Semi-structured interviews were performed with training experts from commercial and military aviation ($n = 8$), as well as the medical ($n = 1$) and maritime ($n = 1$) domain. The experts were asked to list examples of negative transfer that they have observed or experienced themselves. Follow-up questions addressed training approaches and solutions regarding these examples. Answers were categorized using a transfer framework. The experts' most salient concerns involved: Time pressure, which leads to rushed training; Instructors with insufficient understanding of the limitations of the (simulator) training; and the way in which trainees should be placed into hazardous situations in a realistic manner. The experts provided several factors and recalls of experiences which may lead to negative transfer. These results may be relevant for instructors and can provide input for further experimental research regarding negative transfer.

1 | Introduction

On November 12, 2001, an Airbus A300 of American Airlines Flight 587 encountered wake turbulence from a preceding departing aircraft, shortly after take-off from John F. Kennedy International Airport. The aircraft upset caused the pilot flying to use excessive rudder input in both directions, over-stressing the rudder and causing it to depart the aircraft, which resulted in a fatal crash.

According to the National Transportation Safety Board (NTSB) the contributing factors were the characteristics of the Airbus A300-600 rudder system design, as well as elements of the operator's Advanced Aircraft Maneuvering Program (National Transportation Safety Board 2004). Regarding the latter, it states that the simulator 'scenario was unrealistic and might have had the unintended consequence of providing pilots with negative training in how to respond to wake turbulence. The presentation of an unrealistic scenario and the inhibition of flight controls could cause a pilot to develop control strategies that were effective in the simulator but might be inappropriate or even dangerous in an actual airplane' (National Transportation Safety Board 2004, 142) and '[...] simulator exercise could have caused the first officer to [...] erroneously associate wake

turbulence encounters with the need for aggressive upset recovery techniques; and develop control strategies that would produce a much different, and potentially surprising and confusing response if performed during flight.' (National Transportation Safety Board 2004, 143).

This example describes an accident for which negative transfer of simulator training was identified as a potential contributing factor. Transfer of training[1] refers to the degree to which the competencies acquired during training can be applied in practice or other related situations (Blume et al. 2010). The optimization of transfer is especially important in professions for which training relies largely on simulator technology for various reasons. Positive transfer from the simulator to the target environment is needed for resilient operation (Dahlstrom et al. 2009). As the above example with American Airlines demonstrates, it is also important to consider a possible negative transfer, as this can contribute to accidents when it happens in an environment where safety is a critical dimension (Besnard and Cacitti 2005, 110). It is therefore necessary to understand how negative transfer can be identified, and more importantly, how it can be avoided in training.

Woltz et al. (2000) stated that 'Convincing demonstrations of negative transfer have been infrequent in the skill learning literature.' Also, Singley and Anderson (1989) argued that 'while personal anecdotes of negative transfer are very common, convincing experimental evidence is rare (p. 602).' As described below, we could only find a dozen studies in more recent literature that specifically deal with negative transfer. Most studies were performed in a laboratory setting with little validity for the training of professionals such as airline pilots. For this reason, we decided to perform an interview study with training experts to learn from their experiences with negative transfer in a more relevant training environment. Before we present the results of these interviews, we will provide further background on transfer in the next three sections of this introduction: Definitions; Transfer of training framework; and Literature.

1.1 | Transfer of Training Definitions

In general, the literature distinguishes between three types of transfer in terms of effectiveness: Positive transfer, zero/no transfer, and negative transfer. *Positive transfer* can be defined as 'The degree to which trainees effectively apply the knowledge, skills, and attitudes gained in a training context to the job' (Baldwin and Ford 1988, 63). Learning behaviour must fit the job context and should be maintained over time for transfer to be effective. This general definition focuses on the transfer of acquired competencies in formal training. However, learning also occurs in other contexts (e.g., on the job), and positive transfer can take place when learning in one context improves performance in another context (Perkins and Salomon 1992). *Zero or no transfer* occurs when training has no effect on performance on a given task in practice (Borgvall and Nählinder 2008; Ellis 1965; Burke 1997). This means there is neither a positive nor negative effect of training, thus it was not effective.

Negative transfer refers to situations in which learning in a training environment results in the degradation of performance in practice (Alexander et al. 2005; Borgvall and Nählinder 2008; Ellis 1965; Burke 1997). Transfer to the new context is negative when performance in a new context or task becomes worse or when mistakes are being made compared to the previous situation or the training context (Woltz et al. 2000). According to Annett and Sparrow (1985), negative transfer mostly occurs when two tasks, or variants of a task, are very similar in the training context but differ in essential aspects. Although in such situations transfer is mostly positive, negative transfer can be significant when it pertains to crucial elements of the task.

1.2 | Transfer of Training Framework

Figure 1 depicts the popular framework for transfer of training proposed by Baldwin and Ford (1988), which describes the importance of training inputs (i.e., trainee characteristics, training design, and work environment) on training outputs (learning and retention) and the key transfer outcomes: generalization and maintenance.

Training inputs refer to the characteristics of the trainee (ability, personality, and motivation), elements in the training design (e.g., the content, the quality of the instructor, fidelity of the training context, and sequencing of training materials) and the work environment (e.g., support from the supervisor and colleagues and the opportunities to practice the learned skill) that may affect the outcomes of training and the transfer to practice. *Training output* refers to the outcomes of training, what has been learned (e.g., type of knowledge, skills, and competencies) and retention (i.e., how well the content of learning is remembered over time). *Conditions of transfer* are seen as how well newly learned skills can be applied in a variety of situations in the work environment (i.e., generalization) and be practiced and used in the work environment (i.e., maintenance).

To date, this framework is still in use as a guide to study transfer and it has been extended with more training input factors, such as self-efficacy and anxiety of a trainee (Cheng and Hampson 2008; Ford et al. 2018); the use of multiple learning strategies and the explicit incorporation of errors during training (Baldwin et al. 2009; Ford et al. 2018).

When discussing transfer, it is important to consider which competencies, skills, knowledge, and attitudes (SKAs) are trained (Baldwin et al. 2009; Barnett and Ceci 2002). In this, we distinguish between high-level and task-specific competencies. High-level competencies are competencies that go beyond the task, such as flexibility, critical thinking, and communication skills. Task-specific competencies are competencies to execute a specific task, such as driving a car, and relate to skills that are composed of multiple elementary subskills (Van Merriënboer and Kirschner 2007). For example, when driving a car, one needs to have the subskills of knowing how to accelerate, brake, shift gears, look around, etc. If drivers are incapable of executing or integrating one or more of these tasks, they are not competent to drive. Thus, each task has different skill requirements and different training input factors may be needed to achieve the transfer of different task competencies (Barnett and Ceci 2002; Blume et al. 2010).

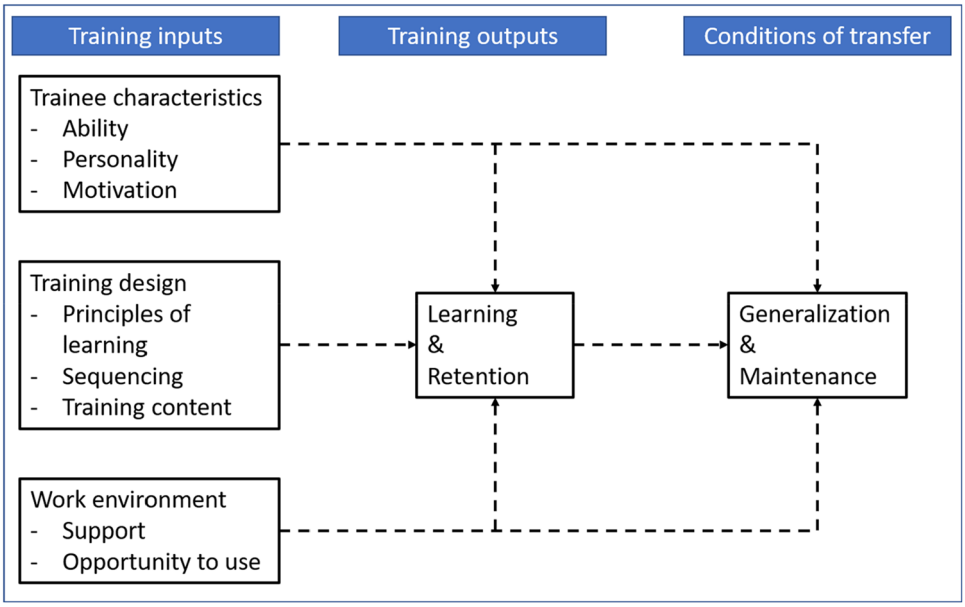

FIGURE 1 | Transfer of training framework (Baldwin and Ford 1988). The list of examples provided per training input characteristic is not exhaustive. [Color figure can be viewed at wileyonlinelibrary.com]

1.3 | Literature on Negative Transfer

We found a scarce number of studies that focused on negative transfer from a variety of domains: aviation (e.g., Hendrick 2002; Lyall and Wickens 2005; Nussek et al. 2008; Rayman 1982; Thatcher et al. 2006), office work (e.g., Besnard and Cacitti 2005; Singley and Anderson 1989), business economics (Finkelstein and Haleblian 2002), linguistics (Bardovi-Harlig and Sprouse 2018) and education (e.g., Chen and Daehler 1989; Landman et al. 2022; Landrum 2005).

Several papers identified s*urface similarity* and *structure dissimilarity* as important task aspects related to negative transfer (Bardovi-Harlig and Sprouse 2018, Besnard and Cacitti 2005; Chen and Daehler 1989; Finkelstein and Haleblian 2002; Hendrick 2002; Landrum 2005; Lyall and Wickens 2005; Rayman 1982; Singley and Anderson 1989; Woltz et al. 2000). When two tasks look similar (*surface similarity*) and are also similar in underlying structure (e.g., rules, goals, controls etc.; *structure similarity*) the required SKAs are similar, and usually transfer to the new task more easily. However, when both tasks look dissimilar (*surface dissimilarity*) and are also dissimilar in structure (*structure dissimilarity*), the SKAs may not transfer to the new task. There are two ways in which surface (dis) similarity and structure (dis)similarity can induce negative transfer. Especially when the new situation shares common features with the previous one, one is likely to incorrectly apply methods learned in the previous environment (Borgvall and Nählinder 2008; Chen and Daehler 1989; Ivancic and Hesketh 2000; Singley and Anderson 1989). It is often stated that variability of practice could result in better transfer (Van Merriënboer and Kirschner 2007). Landman et al. (2022) showed that variability of practice could lead to negative transfer in case variability in practice was either too low or too high.

Prior experience and *automation of skills* may result in habits that negatively transfer to a new situation (Hendrick 2002). In linguistics, this kind of 'interference' is observed when people learn a new language and incorrectly use words from a previously known language (Bardovi-Harlig and Sprouse 2018; Borgvall and Nählinder 2008; Perkins and Salomon 1992). In the study of Finkelstein and Haleblian (2002), prior experience in business acquisition also interfered with learning skills for a new job. In aviation, habits learned in one aircraft type may inappropriately transfer to a new aircraft type with a physically similar cockpit, but slightly different procedures (Hendrick 2002; Rayman 1982).

Other papers address the possible *role of simulators* in negative transfer (Myers et al. 2018; Woltz et al. 2000). The training for abnormal events in professions such as aviation strongly depends on the use of simulation because practice in real life may be too expensive or unsafe. However, simulators are never exact replicas of the real-world situation. Most simulated environments have limitations, for example in motion cueing (e.g., vibrations or g-forces) or sensory cueing (e.g., smell or heat) or experienced stress or anxiety (lack of real consequences). Such deviations from the real world can affect transfer (Myers et al. 2018; Woltz et al. 2000), especially in situations where high stress and surprise are implied (Casner et al. 2013; Schroeder et al. 2014; Landman et al. 2017a); The effect of surprise and stress complicate the sense-making of a situation needed to find the proper solution (Landman et al. 2017b).

Myers et al. (2018) emphasize the *importance of the instructor* for the transfer. The instructor must know the training objectives and training scenarios, as well as the capabilities and limitations of the training environment. Lacking knowledge in the latter may lead to negative transfer.

2 | Current Study

In some of the described studies, observed effects of negative transfer were of little consequence. For example, negative transfer in using text editing programmes (Singley and

Anderson 1989) or problem-solving (Chen and Daehler 1989; Landrum 2005), and sufficient time to 'practice away' the negative effects can be provided. This is different for the training of safety-critical SKAs. For example, when training in skills needed to manage airplane upset, it is difficult to offer trainees sufficient opportunity to practice and maintain those skills). Mainly because training for such skills is expensive and time-consuming.

In the present study, we investigate how factors related to negative transfer are recognized and play a role in operational training practice by interviewing professionals working in safety-critical domains. The primary focus was on training for commercial pilots, but also other domains with high-performing professionals, such as medical, air force, and the navy are explored. We used this study to identify research questions for an experimental campaign in which we were going to investigate negative transfer.

3 | Materials and Methods

3.1 | Design and Participants

A semi-structured interview study (cf. Adams 2015) was conducted with a convenience sample of 10 training experts from our professional network in the following fields: Commercial aviation ($N = 7$), Military aviation ($N = 1$), Maritime ($N = 1$) and Healthcare ($N = 1$). We only approached experts in teaching and training development who also had extensive experience in the operational context that was relevant to the skills being learned. This resulted in the following inclusion criteria: (1) having extensive operational experience in their field (The participants had thousands of hours of experience in their specific domain. In the aviation field this meant more than 10000 flight hours). (2) Having extensive experience as training instructors and training developers (the participants all had over 15 years of experience being instructors in their domain, e.g., at a large airline or a university medical centre). (3) Preferably, the experts were also involved in educational design and educational policy development.

The participating experts were from the Netherlands ($N = 5$) and several other European countries ($N = 5$). The participants described their current positions as head of training in their organization ($N = 2$), human factors specialist and instructor ($N = 2$), airline training experts and consultants ($N = 2$, or senior instructors ($N = 4$).

The study was mainly focused on commercial aviation. Yet, similar training incidents could occur in other high-risk professions as well. To obtain a broader view than commercial aviation we added three experts from military aviation, maritime, and health care.

All experts were invited to participate in our study through email. Eight experts were interviewed individually and in one interview two experts (Experts 3a and 3b) were interviewed together. Therefore, in the results section, we will refer to the ten participants as Experts 1–9.

3.2 | Procedure and Interview Guide

All interviews were conducted by two or more researchers: one led the interview and the other(s) made notes. The interviews were not recorded but notes were taken during the interviews and digitized directly after each interview. The researchers were human factors specialists and educational scientists with extensive experience in qualitative research and expertise about the domains under investigation as well as transfer in high-risk professionals' training.

The semi-structured interviews with the international experts were conducted via telephone, and interviews with five Dutch experts were held face-to-face. The duration of the interviews was about one and a half hours. We usually started the interview with an introduction of the topic, explaining what negative transfer is, why we were conducting the study, and providing information about anonymous reporting and consent. All participants consented to anonymous participation in the study. After the introduction about the goal of the study and a definition of negative transfer, we started the official interview with questions about the expert's background and experience. Since these were semi-structured interviews, we proceeded with the questions in our interview guide. The first question always was whether the expert knew any examples of negative transfer, or whether they had experienced it themselves. Follow-up questions served to obtain more in-depth information, for example, by asking them to explain these experiences further and speculate on what may have caused them.

Other questions in the interview guide were:

- What should one avoid that otherwise could lead to negative transfer?
- Did you observe changes in the training that have led to positive or negative transfer?
- Are there situations in your field that raise concerns for negative transfer?
- What is your opinion on deliberately letting things go wrong in a training setting to demonstrate how to deal with such a situation?
- To what extent is the training in your field standardized?
- How do you know that the existing training is good training?

3.3 | Analysis

After digitizing the interviews, we sent the notes back to the experts to check for completeness and correct interpretations of what was being said. After receiving confirmation from the experts that the notes were complete, we started the analysis.

One of the researchers coded the interviews using deductive coding the *transfer of training framework* presented in Figure 1 (Baldwin and Ford 1988). The quotes of the experts were first coded into the broader categories: input factor, output factor or conditions of transfer. Then the codes were coded into the more

detailed categories underlying these broader categories. For training input, these were: trainee characteristics, training design, and work environment. In the third step, the quotes were clustered to identify specific factors recognized by the experts. For example, ability (trainee characteristics) or training content (training design). Some identified factors were not in the original framework. These were added to the model using open coding. For example, stress (trainee characteristics) and training fidelity (training design). The coded codes were discussed with the other researchers to obtain consensus.

4 | Results

Although their usual focus is on positive transfer, the experts were keen to discuss the topic of negative transfer. All agreed that the effects of (their) training are not commonly measured, partly because a large part of the training is mandated. This means there is hardly any evidence on transfer available in their practice.

After analysing the interviews, it turned out that no factors were mentioned related to training outputs or conditions of transfer (Figure 1). All factors could be categorized into 'training inputs' (trainee characteristics, training design, work environment, and task characteristics). Some factors, however, seem to fall into several categories. For example, when discussing stress (personal characteristic—stress), the experts mentioned how the instructor should consider stress in training (training design—the instructor's role).

The experts also brought up new factors not in the framework, which could also be clustered within training inputs. These factors included: Fidelity of the training environment (either simulator or aircraft), time constraints, training approach, role of the instructor, and whether it is acceptable to 'deliberately let things go wrong in training'.

4.1 | Factors Considering Trainee Characteristics

This section highlights factors in relation to trainee characteristics. The main topics discussed by the experts were: Stress, prior experience, education level of ability, and personality and motivation.

4.1.1 | Stress

According to Expert 4, about 70% of the trainees experience some kind of fear of failure, or performance stress, during flight training. This can result in the learning of incorrect behaviour and consecutively to negative transfer. Instructors should thus create a safe learning environment (Experts 3, 5, 9). Experts also recognized that stress in simulators does not match stress induced by threats in the real world and that people may revert to old habits under stress. This is particularly the case in unexpected situations (Experts 5, 7). To mitigate this, basic skills should be well-trained and become automated, so that people can act appropriately out of 'muscle memory' during stressful, unforeseen situations (Experts 2, 5).

4.1.2 | Prior Experience

Prior experience can hamper transfer, especially when skills have been automated, for example, motor skills/muscle memory (Experts 2, 4). As described under the factor 'stress,' in stressful or unexpected situations, trainees may revert to old habits. For example, conversion to another aircraft may require extra training to unlearn certain (automated) habits that worked in the previous aircraft type (Experts 2, 3, 4).

Some pilots have difficulty with changes in tasks, platforms or operational environment (Expert 4), which could be due to their level of ability. In such cases, prior experience hampers training and operational performance. For this reason, some airlines have reservations about hiring pilots with a military background (Experts 3a, 3b), because the way of flying in the military is different from operating a passenger airline.

4.1.3 | Personality and Motivation

Trainee personality and motivation were also important factors mentioned by the experts. For example, over-confident pilots may act instantly without thinking (Experts 1, 8). Also, less dominant pilots may be overshadowed by dominant instructors or copilots, which can result in less or negative transfer when proposing incorrect techniques or knowledge (Expert 4). According to Experts 4 and 9, whether transfer is positive, zero or negative also depends on the willingness of the student to learn new skills and to apply a newly learned skill into practice (Experts 4, 9).

4.2 | Training Design

This section highlights factors in relation to various elements of training design that could lead to negative transfer. Topics discussed were training content, pretending, fidelity of the training environment, time constraints, role of the instructor, and deliberately letting things go wrong.

4.2.1 | Training Content

Several experts (Experts 2, 6, 7) mentioned that flight training is often very traditional (i.e., involving many procedural tasks and checklists, and rehearsing safety-critical skills until these become automated). Although traditional training makes these skills easier to apply under stress, it is less suitable for situations that do not have a clear cause or appropriate procedure. In such situations, trainees tend to revert to a checklist instead of thinking and finding out what the root cause of the problem is. The experts were concerned that overreliance on traditional training could create 'procedure monkeys' instead of problem solvers, critical thinkers or adaptive experts. Many serious incidents in aviation could not be solved by applying a procedure or checklist but have been solved using problem-solving and knowledge of the aircraft. Instead of only training by repetition, pilots should be taught to solve a variety of unexpected situations, allowing them to make errors in doing so (Experts 2,

3, 4). A mentioned example of the negative consequences of traditional training was:

> *The 'training of an engine failure before V1', where pilots were checked on their quick response (i.e., within 1 s) to abort take-off so that the aircraft can come to a full stop before the end of the runway. This scenario was trained very often to make sure the pilot's response was induced by automatism. However, in real-life, when confronted with a tire burst, 90% of the pilots also aborted the take-off, which in the case of a tire burst is not the correct response (because after a tire burst, break capacity is limited to 50% which means you can never stop before the end of the runway).*

4.2.2 | Pretending

In training scenarios, trainees are sometimes asked to pretend that they perform certain actions or to practice a simplified version of the actual action instead of performing a realistic version of the complex action. The medical expert advised against this, as this could lead to negative transfer. For example:

> *There is a certain anesthetic medication which is very difficult to solve, requiring about 15 ampules and extensive collaboration to achieve a good solution. Normally, this is being trained by using a simple NaCl solution (i.e., a 'pretend' practice solution), which can be prepared and executed by one person in time to save the patient. However, when the medication was needed in a real emergency, it turned out that the preparation of 15 ampules could not be performed by one person without the help of others, which led to frustration on one occasion.*

Practicing this in training by themselves with less medication and without collaboration thus led to an unsafe situation in real life. This procedure is now only being trained when real (expired) medicine is available (note that this is not a basic skill). According to this expert, it is better not to train this specialized skill at all than to train it incorrectly or by pretending.

4.2.3 | Time Constraints

Several experts emphasized that time constraints have a large impact on the content of (simulator) training, which may lead to: (1) Encouragement to rush to a (suboptimal) solution, while in real situations it is better to think before acting (Experts 1, 2) or (2) Selection of training content at the cost of other exercises, which may result in overlearning of the selected skills or situations (Experts 1, 2, 6, 7), such as the engine failure at take-off. Both consequences of time constraints may lead to a bias in responses towards the practiced situation, which may be inappropriate in different situations (Experts 1, 6, 7). Expert 2 described an example from his own training in which the instructor ordered him to land in an unsafe place due to training time constraints:

> *I decided that the safest solution was landing at an airport near the coast at quite some distance from the current location. The instructor told me that it was a good decision but asked me—due to time constraints of the simulator session—to land on a nearby small landing spot in the mountains. However, in real-life you would never choose to land in the mountains. This way I could have been taught that it was a good idea to land in a location that is less safe than the alternative. The instructor could have aborted the scenario after telling me that I had made the correct choice. That would have been a better solution.*

4.2.4 | Fidelity of the Training Environment

According to several experts, a realistic training setting is important for positive transfer of skills (Experts 1, 4, 5, 8, 9). Some general skills and procedures may be trained in a less realistic simulator if relevant (functional fidelity; Experts 6 and 9). For example, when training cognitive skills, cognitive fidelity is more important than physical fidelity (Expert 6), but aircraft-specific skills should be trained in an environment that behaves like the target aircraft (Experts 3a, 3b). For example, the training of flight handling skills in a small aircraft may negatively transfer to large (transport) aircraft, because both aircraft types behave differently. Therefore, Experts 1 and 8 advised against using small aircraft for the training of airline pilots.

4.2.5 | Role of the Instructor

All experts agreed that, first and foremost, an instructor must create a safe learning environment, taking trainee characteristics into account. For example, the training can be adapted to the trainee's abilities and signs of stress (Experts 5, 7, 8). An instructor can affect whether a trainee feels motivated and encouraged during and after training, which can influence (negative) transfer (Experts 2, 4). The instructor should stay focused on the simulation and the trainee's behaviour.

According to Experts 8 and 9, the instructor plays an important role in bridging the gap between simulation and reality. Especially when the simulator is of lower fidelity, debriefing on the differences with actual situations is important. Instructors should be aware of potentially inappropriate habit formation (Expert 2). This is often overlooked because only the outcome of a task is considered. Expert 2 recalls the following example of this:

> *While landing a full and heavy 737–900 in a simulator, a trick is to correct a late flare with a power-on landing to avoid a hard landing. I later learned in real-life that when you touch down with the power on (above a certain limit) and the plane bounces, the system retracts the*

spoilers, which means that the plane starts flying again. Obviously, it would not be a good idea to continue the landing, even though in training this seemed a useful trick.

The instructor should therefore have up-to-date knowledge and focus on the process of the task performance instead of only on the result (Experts 2, 7). This is especially important when they (i.e., the instructors) also impact the trainee's behaviour (Experts 1, 4, 8).

Instructors can use mistakes in the training as a learning opportunity and provide helpful feedback about the correct technique. However, deliberately letting a student fail and crash, or forcing them to make inappropriate choices (e.g., because of limited time) should be avoided according to the interviewed experts. A failure or crash could lead to fear of failure (Experts 2, 3, 7, 9), and inappropriate choices could lead to overconfidence in real life (Expert 2).

4.2.6 | Allowing Trainees to Deliberately Let Situations Go Wrong

Certain procedures are difficult to train in a training environment, especially when it concerns procedures to manage situations where things have gone wrong. Deliberately letting things go wrong may require unrealistic behaviour from the trainees, because they would need to refrain from immediately responding to precursor warnings or cues. An example from aviation is the recovery of an aerodynamic stall, which may require trainees to delay their response to stall indications to which they should promptly respond in real life. The opinions of the aviation experts varied on this point. Two experts (Experts 3a, 3b) regarded this as not being a problem since in their opinion trainees should be able to distinguish the training situation from real-world situations if properly explained. Other experts (1, 5 and 7) were concerned that this could potentially lead to negative transfer because it would teach pilots to ignore stall warnings. Expert 1 noted that the timing of such training should be carefully chosen. For example, deliberately ignoring stall warnings to practice stall recoveries, may send the wrong message when it takes place directly after training on how to prevent a stall.

The expert from the medical domain (Expert 9) explained that emergency situations in medicine are being trained using 'take-over scenarios', where the instructor may do something wrong (often without the students knowing), and then hand over the patient to the student. Subsequently, the scenario escalates, and the student must recover from the situation. According to this expert and Expert 7, this is representative of how such situations may occur in practice.

4.3 | Work Environment and Task Characteristics

This section highlights factors in relation to various elements of the work environment and task characteristics.

4.3.1 | Surface (Dis)Similarity and Structure (Dis) Similarity

When a situation in operational practice looks similar to a training situation while it is not, behaviours learned in the learning context may be wrongfully re-applied in the transfer context (Expert 2). For example, emergency procedures can be largely similar between different aircraft types, but with different details. Thus, when changing to a different aircraft type, these differences in emergency procedures should be trained thoroughly.

4.3.2 | Insufficient Backup in the Workplace

The medical expert mentioned a case where learned skills were not being transferred to the work environment because it was not supported by supervisors and (senior) colleagues.

In our medical field we provide crew resource management (CRM) training. Looking at the Kirkpatrick levels of training evaluation we see that the trainees liked the training, they learned the CRM skills, and applied it in practice. However, time constraints and the hierarchical nature of the job prevents transfer of CRM skills to practice as senior employees who have not received the training do not see the necessity. Even though literature has shown that 70% of all medical mishaps occur due to errors in CRM.

This example may not be a negative transfer but still hampers the desired effect of training effectiveness and transfer to the workplace.

5 | Discussion

The present study describes an interview study with training experts in safety-critical professions on potential factors involved in negative transfer. The interviews provided information in addition to the literature, including several examples of negative transfer from training practice. The interviews also showed that there are controversial opinions about certain training approaches (e.g., 'how to handle a trainee who fails in the training', or 'deliberately flying into a stall in a training simulator'). These controversies point to the lack of empirical evidence on these issues, which may be a reason for new research.

Although one would expect that simulator fidelity plays a dominant role in discussions on negative transfer, the experts pointed out a variety of other factors that raise concerns about negative transfer. An important topic that came up in several interviews is the traditional focus on procedural (pilot) training, where it may be better to train competencies that allow pilots to deal with various situations. Still, pilots also need to be proficient in basic (procedural) skills, and the challenge is to find the correct balance between automation of these skills versus the acquisition of generic competencies, such as problem-solving, which are needed in unexpected situations such as emergencies.

A related topic brought forward is the impact of time constraints on (pilot) training. Time constraints work negatively in two ways. First, tasks are often trained in the context of one (and the same) situation, so that students develop a bias of responding in a certain way that may not be appropriate for other situations. In the future, more variability of practice could be added in training. Second, time constraints may encourage instructors to cut scenarios short, leading to unfinished or rushed exercises. This occurs often in expensive training, personnel shortages or when the workload is high. The possible negative effect of rushing or aborting training scenarios on later operational practice should be further explored.

The instructor's role was also a central issue in the interviews. The instructor is not only crucial for avoiding negative transfer but also for improving training effectiveness in general. The instructor should create a safe and open learning atmosphere, to reduce any negative side effects such as performance anxiety or fear of failure. Furthermore, the instructor has an important role in bridging the gap between (imperfect) simulator fidelity and reality. This requires that the instructor has a good understanding of the limitations of the simulator; otherwise, it may lead to reinforcement of negative training (as was the case with American Airlines flight 587, described at the start of this paper).

5.1 | Limitations and Future Directions

We want to emphasize several limitations of this study. First, the experts were drawn as a convenience sample from our professional network without specific inclusion or exclusion criteria. The main reason to approach them was their extensive experience as an instructor or as other training specialists.

Second, the interviewers did not receive specific interview training, and third, the interviews were not recorded. However, all researchers were experienced researchers in qualitative research and were knowledgeable about the topic and the domains under investigation. Also, the notes of the interviews were shared with the experts for checks of completeness after the interview notes were written out. Although this could have hampered quantitative analysis to some extent, we are confident that we grasped the essence of what the experts shared with us. Still, in the future, we will use recording devices or online meeting tools with transcription software to support our research.

Finally, the number of participants was relatively small, because we selected participants who were regarded as experts in their domain, and who had extensive experience in teaching. We have the impression that we reached saturation of information with this group of experts because after interviewing seven experts in commercial aviation, no new information about factors related to the negative transfer of training was obtained by adding three experts from different high-risk domains (i.e., military, maritime, and health care).

The interviews helped us identify research topics for follow-up studies. For example, (1) the effect of variability of practice instead of procedural training, which was a concern mentioned by three experts; (2) the effect of going beyond warnings and deliberately letting things go wrong. This is a concern that is also mentioned by several experts, however, some procedures are too hard to train without going beyond warnings. It is necessary to study whether ignoring warnings to get to the required training point indeed leads to negative transfer in the real world.

5.2 | Implications for Practice

Although there is a substantial amount of literature on positive transfer, only a few papers exist on negative transfer. This interview study shows that training experts are usually more concerned with improving positive transfer, rather than avoiding negative transfer. However, when challenged to think about the topic, they were able to identify several factors, or 'pitfalls', which may lead to negative transfer. For instructors, the most important takeaways from this study include: creating a safe environment; signalling wrongly learned behaviour, even when the outcome is adequate; knowing the limitations of the simulator device; avoiding time constraints of the training having an impact on the trainee's decision making; trying to find a balance between the training of routine and adaptive expertise. For educational designers and designers of training simulators: be aware of the effect of differences in the simulated environment and the real world. Small differences can have detrimental consequences on operational performance. When designing simulators, carefully consider when it is crucial that elements are the same or similar, and when it is not to avoid negative transfer from the simulator to the real world.

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Conflicts of Interest

The authors declare no conflicts of interest.

Endnotes

[1] From now on referred to as transfer throughout the manuscript.

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