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FULL PAPER

Effect of practice on similar and dissimilar skills in patient transfer through training with a robot patient

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ABSTRACT
With the number of hospital stays increasing, nurses require more training to handle a variety of patients. However, time for training in nursing schools is limited, and students lack the opportunity to practice on a diverse variety of patients. Using a robot to simulate actual patients, this study observes the learning transfer effect of practice on practice-similar and practice-dissimilar skills from one patient to another, and investigates which types of practice suit which kinds of training. An experiment was conducted by administering a pre-test, practice, a post-test, and a transfer test to two groups ($N = 8$), each with different practice-related skills. The evaluation used a checklist covering required skills that were either similar or dissimilar across groups, depending on their practice. The effect of practice can be observed through a comparison of skills similar to one group but dissimilar to the other. The results show that practice facilitates learning transfer on similar skills but not, or to a lesser degree, on dissimilar skills. Furthermore, if skills needed to handle given symptoms are unfamiliar or inaccessible to students, practice related to those symptoms should be emphasized through simulated training with robots.

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1. Introduction

According to United States statistics, the number of hospital stays has increased by a by a million from 2003 to 2008 [1]. Due to this increase, hospital nurses should have the skills necessary to care for a wide range of patients suffering from various symptoms [2]. However, nursing education as it is currently conducted is not sufficiently responsive to train nursing students to treat a variety of patient types. After nursing students graduate, it takes several years for them to become experts at hospital work [3]. Even at the expert stage, they lack confidence in caring for patients whose ailments were not covered in school [4]. The following facts may underlie and explain this situation. First, nursing students cannot practice their skills on actual patients for ethical and safety reasons; therefore, it is difficult to obtain the needed practical experience [5]. Second, as a result of this practice limitation, nursing students do not get the chance to learn the skills to treat a wide variety of patients. Similarly, they do not have sufficient time at school to practice and repeat all necessary skills before starting work at a clinic or hospital [6–8]. Thus, two steps have become vitally important: improving nursing education so it satisfies hospitals' demand for nurses who are trained to deal with a variety of patients and determining what kinds of practices are essential when training students.

To enhance student learning, the knowledges of both motor learning and simulated learning were employed. Motor learning is a common method used to enhance student learning by practice or experience [9]. Under this concept, practices, such as wrist rotation tasks [10], have been widely employed to improve different motor skills. Simulated learning, a learning technology that allows learners to practice in simulated conditions, is one way to overcome the problem of nurses' deficiency in practiced skills. A simulated patient is indispensable in an ideal nursing education because the patient plays the role of the recipient of the nurse's skills, and, due to safety and ethical concerns, students usually have limited access to actual patients on which to practice. Simulation-based practice facilitates the transfer a of a learned skill to a target situation [11,12] and has been widely applied to various fields, such as a virtual reality environment in a dance training system [13] or driving and flight simulators used

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to train drivers and pilots [14,15]. Diversified simulators were developed for and have been employed in surgical training [16]. Moreover, simulation learning has also been applied in nursing education for decades [17].

In the fields of medical and nursing education, simulated patients can generally be divided into two types. One is the standardized patient (SP), and the other is a human patient simulator (HPS). SPs are patients simulated by individuals with clinical experience who are trained to portray patients with diseases and conditions by mimicking their symptoms, while HPS is a nonhuman simulated patient, such as a mannequin or a robot. SPs have some problems when used for education. First, it is difficult for a single individual to learn to simulate a wide range of symptoms because doing so requires extensive clinical experience and knowledge of varying types of patients. Second, it is difficult to recruit and train SPs for special populations such as children [18]. With regard to HSPs, the first mannequin was introduced to teach physical assessment to student nurses in the UK in the 1950s [19]. However, there are also difficulties with using HSPs, particularly in teaching student's patient interaction skills or voluntary patient behaviors, because a stationary mannequin cannot reproduce patient movements. Thus, robot HSPs were developed that had mechanisms (e.g. motors) that enabled them to simulate patient movement. A single robot HSP could also be programed to reproduce different symptoms, enabling the student to learn a variety of patient conditions. Because of these advantages, robot HSPs are prevalent today.

As technology has progressed, HSPs with more functions have been developed for training purposes. For example, upper and lower limb robots [20,21] were developed to train physical therapists by simulating the behaviors of humans afflicted by spasticity, contracture, and rigidity. Similarly, a computerized human patient simulator was employed in trauma management training [22], while a mannequin was developed for clothes-changing practice during nursing training [23]. Some robots are used in diagnosis training for medical students, such as prostate [24] and cardiology simulator robots [25], which reproduce abnormal prostate conditions and heartbeats, respectively. In addition, an epidural injection simulator with force feedback was developed for medical training [26], and a dentistry robot with human-like teeth and gingiva was developed for clinical training [27]. Other researchers have introduced robots to simulate patients with airway and swallowing function difficulties [28] to enable rehabilitation [29]. In some of our earlier studies [30,31], a robot patient was developed and implemented for transfer training. However, although the simulator and robots were capable of simulating actual patients, no study has evaluated whether the transfer of learned skills from a simulated patient to a real one occurs in nursing students. If practice at school is transferrable in this way, it can facilitate nurses' ability to deal with various patients when working at a hospital. Furthermore, even though the robots were developed to reproduce diverse patient situations [24,25,31], the time available for training at school is limited. In this context, verification is required regarding how to use the robots to incur the most benefits to students.

Learning transfer is usually described as a process in which prior experiences or learning are converted into performance in a new situation [32]. Many studies have explored the transfer of learning from one context to another similar context. For example, in a study by Coldwells and Hare [33], a tennis experiment was conducted on children, revealing that short tennis (mini tennis) skills transferred positively to lawn tennis. In soccer, positive transfer of learning has been found from hand juggling practice to juggling with the knees and a subsequent ball control task [34]. Other existing studies state that trainees who practiced the board game Reversi (Othello) experienced learning transfer to the game Go [35]. If learning transfer can be enabled through simulation training, as these findings imply, it will be more efficient and more beneficial to students, who will otherwise find it impossible to experience heterogeneous types of patients and symptoms.

However, some studies showed [32,35] that only skills that are similar to those used during practice have a measurable learning transfer effect. Some studies also claim that similarity is the main factor determining whether learning transfer can occur [35,36]. This conclusion applies to general learning concepts, but whether this concept is applicable in nursing skills remains unknown. Therefore, it is necessary to investigate what kind(s) of practice can be transferred to skills used to handle various patients, to what skills each kind of practice can be transferred, and under what circumstances the skills can be transferred.

On the basis of the above, patient-handling skills can be categorized into the same skills learned in practice, similar skills, and dissimilar skills, based on the relatedness of a patient's condition to that experienced in the practice. Same skills can be transferred in a straightforward fashion; therefore, to understand learning transfer to new skills in new contexts, similar and dissimilar skills should be analyzed. Similar skills are used to handle patients who suffer from symptoms students have practiced treating. In contrast, dissimilar skills are skills used to deal with patients suffering from symptoms that the caregiver has never practiced treating and that are not related to practice. If learning transfer can occur for those skills, students' education can prepare them for the range of different patients they may meet in hospitals, while if the skills cannot be transferred based on practice, they must be explicitly taught to equip practitioners to handle these patients.

Due to the importance of the procedure to the patient's quality of life and the difficulty of full-body interaction between nurse and patient, this study aims to help improve nurses' skills related to patient transfer. A previously developed robot patient that simulates different types of patients for learning and practicing transfer skills was employed. The purpose of the study is to observe the effects of prior learning on learning transfer of similar and dissimilar skills. A checklist is proposed based on our pre-work [37], in order to evaluate learning transfer and learning effectiveness. It contains the appropriate methods and steps used in patient transfer. During the experiment, four types of patient groups and two experimental groups were established: injured right arm; right hemiplegia; left hemiplegia affecting an injured right leg, with expression of painful sensations; and intravenous line. One experimental group practiced with the first type of robot patient, the other with the second; the last two types were used to measure learning transfer in both groups. Two different practice subjects were used because this arrangement enabled us to measure and compare the practice effect on similar and dissimilar skills and because different types of practice allow further discussion of which practice type is more suitable for the simulation training using the proposed robot. The main contribution of this paper is to conduct an experiment on nursing students. The study used pre- and post-tests to measure the learning effectiveness of practice, while a transfer test evaluated whether learning could transfer to similar and/or dissimilar skills. The results can provide information that may improve nursing education and the use of robots in simulated training.

The remainder of the paper is structured as follows. Section 2 introduces the process of patient transfer across different patient types. Section 3 describes the robot patient. Section 4 describes the experiment and the evaluation methods, then outlines the results. Section 5 discusses and interprets the results in detail. Section 6 concludes the paper with some comments on future studies that can expand the knowledge gained in the current study.

2. Patient transfer skill and target patient

2.1. Patient transfer skill

Patient transfer is a difficult nursing task [38]. This skill requires complicated procedures and interaction with patients, knowledge of human anatomy, and knowledge of the patient's condition. The main actions during patient transfer are presented in Figure 1. The main steps of patient transfer are sitting on the bed, mutual hugging, standing up, pivot turning, setting the patient down on the wheelchair, and final posture adjustment. Although different patients have different symptoms and behaviors, all the procedures follow those main steps.

2.2. Patients with different similarities in symptoms and conditions

Based on a discussion with nursing teachers, patients who require assistance with transfer usually have the following in common: 1) behavioral problems, 2) painful sensations, and 3) constraint from medical devices. To cover these general features and to evaluate the learning transfer of similar and dissimilar skills from practice, four types of patients with different similarities were chosen, as shown in Figure 2: injured right arm with painful sensation and expression (Type I); right hemiplegia (Type II); left hemiplegia affecting an injured right leg, with painful sensation and expression (Type III); and intravenous line (Type IV). Type I and II patients were identified as the two practice subjects, and Types III and IV as test subjects in the transfer test. Type I and III patients have the similar symptom of injured limbs, the former an arm and the latter a leg, while Type II and III patients suffer from the same symptom of hemiplegia but on different sides. For students who practiced with Type I and were tested with Type III, the test enabled us to measure the learning transfer of similar skills related to injured limbs and of dissimilar skills related to hemiplegia, while for students who practiced with Type II and were tested with Type III, learning transfer of similar skills related to hemiplegia and of dissimilar skills related to injured limbs were measured, and for students who practiced with Type I or II and were tested with Type IV, the test could observe any learning transfer of dissimilar skills related to the intravenous line from practice with Type I or II. Detailed descriptions of each symptom are presented below. The reason for dividing students into two groups and practicing with two types of patients was to investigate what kind of practice might have a greater positive impact on nursing training with the proposed robot.

2.2.1. Injured limbs

Injured limbs are common in nursing treatment. This patient will feel pain if the injured part is moved too quickly and will express the location of the pain, such as an injured arm or leg, vocally. To transfer injured patients smoothly and comfortably, nurses should consider patients' perceptions and feelings, such as avoiding abrupt movements that cause pain in injured patients

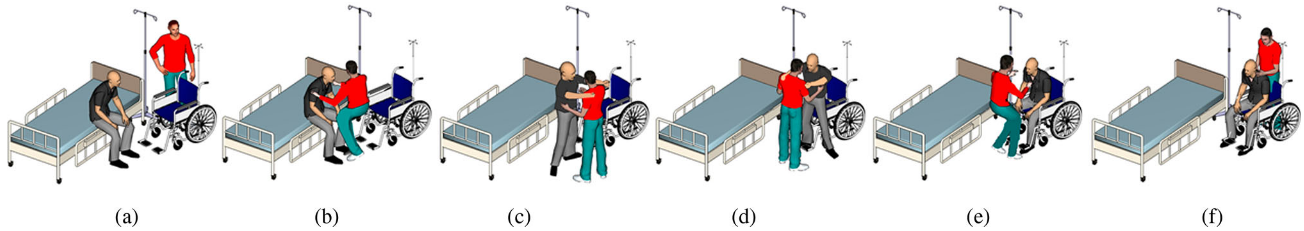

Figure 1. Steps of patient transfer skill: (a) parking a wheelchair (b) mutual hugging (c) standing up (d) pivot turning (e) sitting down, and (f) final posture adjustment.

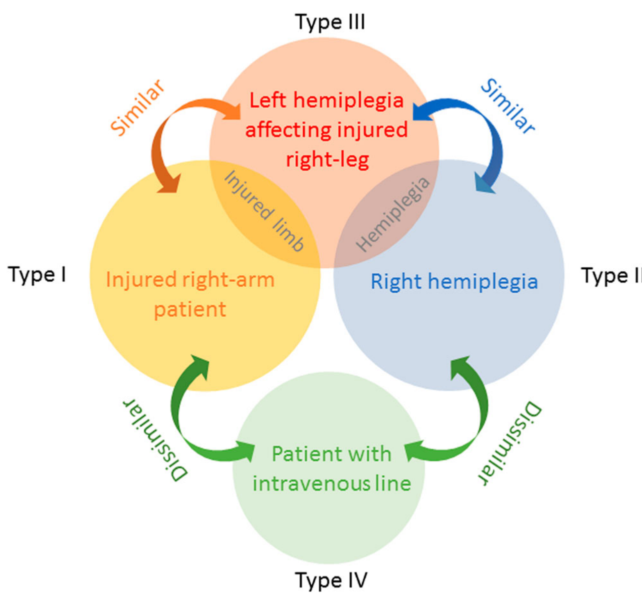

Figure 2. Different similarity among Type I–IV patients.

[39]. For example, to transfer a patient with an injured arm, the nurse should move the patient's arms onto the nurse's shoulder slowly and support the patient by executing mutual hugging to avoid pain. For an injured leg, the same general approach applies, but the nurse should be especially aware of the steps of standing up, pivot turning, and sitting the patient down.

2.2.2. Hemiplegia

Hemiplegia is paralysis in one side of the body, with the distinctive movement of the trunk falling toward the paralyzed side, because patients with hemiplegia subconsciously place their weight in that direction when moving [40]. To transfer a hemiplegia patient, the nurse must place the wheelchair on the patient's non-paralyzed side. The healthy leg can serve as a rotation center for the pivot turn and support the patient's weight, keeping the patient true from bed to wheelchair. In addition, the nurse should support the unstable trunk of the hemiplegia patient especially when sitting on the bed before transfer but also when in the wheelchair.

2.2.3. Intravenous line

Many patients who are hooked up to an IV need to be transferred. In order to transfer IV-attached patients, the nurse should first move the wheelchair to the side upon which the line is inserted, then move the drip infusion from the stand to the wheelchair before transferring the patient [41]. During the transfer, the nurse should avoid interfering with or interposing themselves between the line and the patient and should also be aware of the need to prevent any sudden drop of the infusion and inserted needle.

3. Robot patient

3.1. Hardware

A previously developed humanlike robot patient [31] was used in this study. To imitate the four target patients, we used the same hardware but proposed different control methods to reproduce the different conditions and symptoms. The robot patient comprises a head, upper limbs, waist, hips, and lower limbs, as shown in Figure 3. It has 20 joints in all: 10 for the upper limbs, two for the waist, and eight for the lower limbs. A microphone for voice recognition is installed at the neck, close to the nurse's mouth when speaking face to face or during transfer, and a speaker is located on the left side of the robot's trunk.

The size of the proposed robot patient was meant to reflect the typical specifications of a Japanese female. Its height was 158 cm, while its weight was temporarily reduced from 53 kg to 32 kg, which is 60% of the average Japanese female's adult weight, due to the concern that a heavy load would increase the possibility of lumbar injury during incorrectly executed operations [42]. Also, if necessary, the weight can be adjusted by removing weight units from or adding them to a hollow space within the robot's chest and limbs. During the experiment, in order to avoid damage or injury due to collision, protective sponge materials were attached to the robot.

3.1.1. Upper and lower limbs

To reproduce the actions of human upper limbs, the robot's arms comprise three parts: shoulder, elbow, and

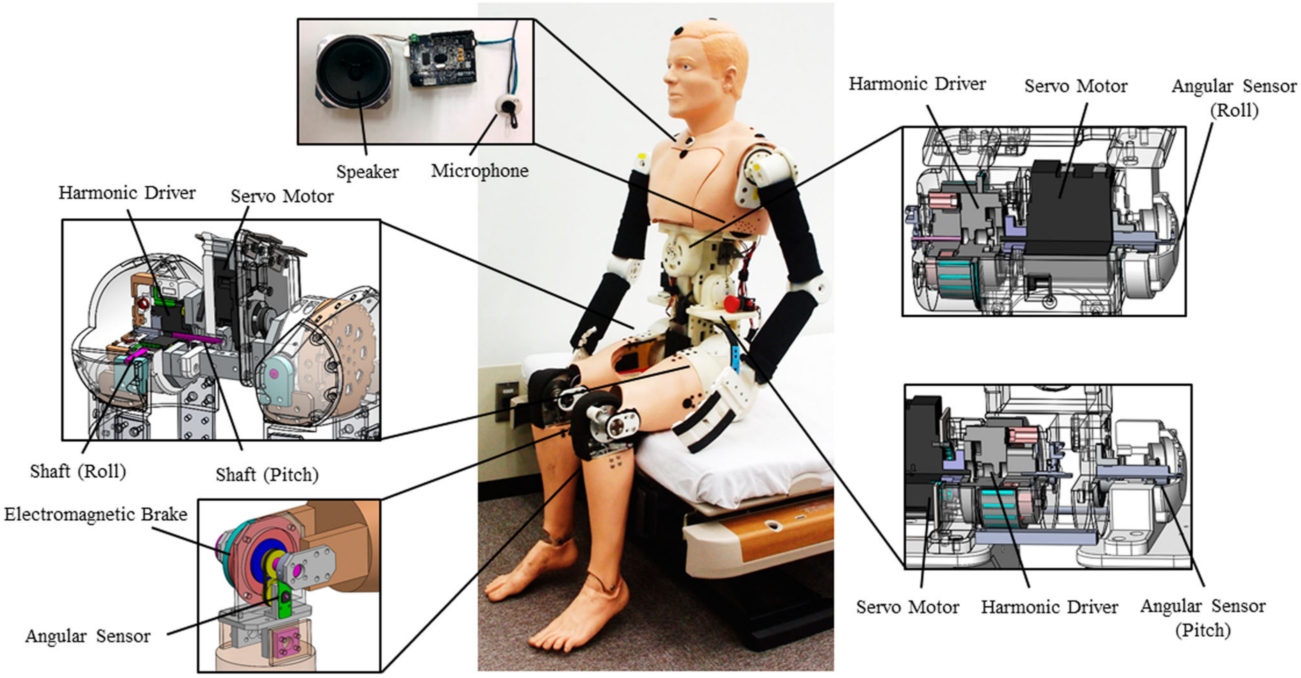

Figure 3. Hardware of the robot patient.

finger. The shoulder joints were designed with three degrees of freedom (DoFs), and the elbow joint was designed with one. Each joint was installed with an angular sensor enabling position control. In addition, the finger joint has one DoF controlled by a motor that allows the finger to grasp and release. The lower limbs include ankles and knees to simulate standing and sitting actions, each with one DoF. An electromagnetic brake and angle sensor are installed in the knee joint, while the ankle is designed as a free joint, enabling the nurses to conduct the final posture adjustment.

3.1.2. Hip and waist joints

The hip and waist joints enable the robot to simulate trunk movements such as collapses caused by paralysis. Each hip joint has two DoFs; pitch rotation uses a motor, while roll rotation occurs through a free joint. The waist joint has two DoFs using similar pitch and roll mechanisms. Both the hip and waist joints are installed with compliant units capable of measuring external force (such as the supporting force exerted by the nurses).

3.2. Symptom reproduction methods

3.2.1. Injured limbs with painful sensation and expression

The first step in the control method for the injured robot's symptoms is detecting the movement speeds of the injured joints; if the speed is greater than the threshold, the speaker will make a sound: 'It hurts.' In this study, pain loci and thresholds were as follows: for patients with an injured arm, the rotation speeds of the shoulder and elbow joints were measured, with the threshold at $> 10°/s$. For right hemiplegia with an injured right leg, the pitch rotation of the hip and knee joints was measured, with a threshold at $> 15°/s$.

3.2.2. Trunk instability and paralyzed limbs in hemiplegia

The trunk instability seen in hemiplegia is the movement of collapsing toward the paralyzed side. The first step of the control method is force-sensing through the waist joints; if no force is detected, the motor will rotate, making the trunk fall down toward the paralyzed side. In contrast, if force exists, the motor will rotate, leading the trunk to gradually follow the force. In addition, to reproduce paralysis of the limbs, the paralyzed joints are set in 'torque off' mode, which simulates the loss of muscle function. In this mode, the motors and brakes are turned off and can be freely rotated by external force.

3.2.3. Intravenous line

The intravenous line was equipped on the robot patient's left arm, and the drip infusion was hung on a stand near the bed. A stainless-steel support pole for an intravenous line was installed on the wheelchair so that the drip infusion could be hung on the wheelchair as well. Because this patient type did not have physical problems, there was no other control method to reproduce their symptoms.

3.3. Subjective evaluation by nursing teachers

Before deploying the robot, its applicability was evaluated with regard to patient transfer pre-work [31]. Three nursing teachers were invited to conduct patient transfer with the robot, imitating all four different patient types. According to the checklist and questionnaire results, the robot effectively simulated the conditions related to transfer. Furthermore, the teachers agreed that the robot intervention would be reproducible and recommended student training using the robot patient.

4. Experiment and results

4.1. Purpose

With the motivation of enhancing nursing students' ability to handle diverse types of patients, this study evaluated the effect of practice on the learning transfer of different skills. To do so, it was necessary ensure a fair analysis of learning transfer by first verifying learning effectiveness in advance. Therefore, an experiment using a pre-test, a post-test, and a transfer test was conducted. The pre- and post-test measured the effectiveness of nursing students' learning, while the transfer test observed the learning transfer of similar and dissimilar skills. Furthermore, we intended to figure out for which symptoms simulated training practice was indispensable for students.

4.2. Participants

The participants were eight nursing students (seven females and one male) in their first and second years at a nursing college in Tokyo. All of them had learned basic patient transfer skills in lecture, imparted by teachers using learning materials (e.g. textbook, video) and a role-playing exercise. Students were randomly assigned to Group A or Group B (four students each). The study was approved by the Ethics Review Committee at Tokyo Ariake University of Medical and Health Science. All the participants were informed about the purpose of the study, and written informed consent was obtained.

4.3. Procedures

The experiment was divided into five stages: instruction, pre-test, practice, post-test, and transfer test. The students were divided into two groups, and each group used different practice subjects, as shown in Figure 4.

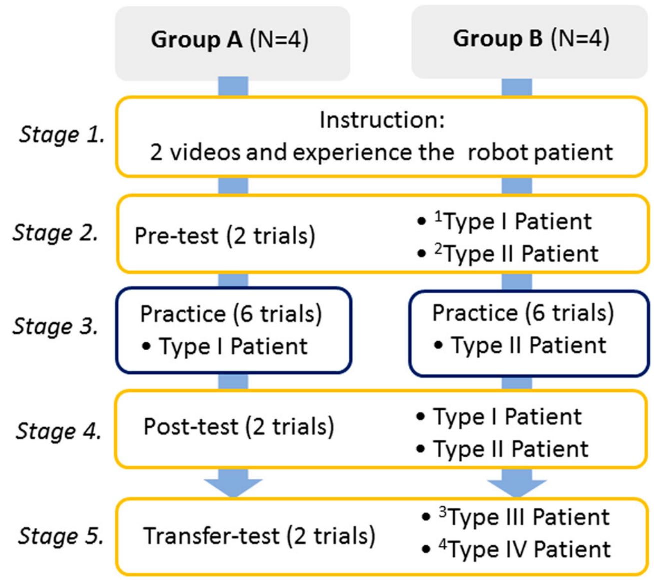

Figure 4. Experiment procedure.

In Stage 1, each group had five minutes to watch two videos. First, an instructional video used in nursing school as learning material introduced the general steps of patient transfer. The students watched this video to review their patient transfer skills and to reinforce the goal of avoiding adversely affecting the patient's symptoms or behavior. Second, a video introducing the robot was shown. After the videos, students received 10 minutes' experience with the robot patient, including the voice recognition module and some attention to their own safety working with the robot.

In Stage 2, a pre-test was conducted to evaluate the students' initial performance before practice. Two robot patient types were used: injured left arm with painful sensation and expression (Type I) and right hemiplegia (Type II). Each student was asked to transfer both types of patients, once each. This study divided the students into two groups to practice with different types of robot patients because it aimed to investigate learning transfer between similar and dissimilar skills and which types of symptoms would provide more benefits for patients if simulated in robot training – for example, if practice with the injured limb or with hemiplegia would facilitate greater learning transfer to different skills.

In Stage 3, the students in each group were asked to practice patient transfer skills. Group A practiced with the injured left arm robot patient with painful sensations and expression for six trials each, while Group B practiced with the right hemiplegia robot patient, again for six trials. The teacher provided feedback to students in both groups during practice.

In Stage 4, the post-test was conducted to examine whether the students' skills had improved after practicing with the robot patient. In each group, the students were asked to transfer two types of robot patients, as in the pre-test, to evaluate learning effectiveness.

Figure 5. Patient transfer trials conducted by nursing student.

In the final stage, Stage 5, the transfer test examined the different effects of practice on similar or dissimilar skills used to treat different types of patients. At this stage, students in both groups were asked to transfer the patient with left hemiplegia with an injured right leg (Type III), and the one equipped with intravenous line (Type IV). To transfer Type III patients, skills related to Type I and Type II patients were required, while to transfer Type IV patients, skills related to intravenous line handling were needed.

All trials in the pre-test, post-test, and transfer test were recorded, for later evaluation by the nursing teacher, from two different angles – front and back views – using two video cameras. An example transfer trial with the robot patient is shown in Figure 5. To ensure the safety of participants during the experiment, a nursing teacher accompanied the students they students carried out the trials. In addition, staff was on standby to catch the robot patient in the event of an accidental drop or fall.

4.4. Evaluation method

4.4.1. Checklist

To evaluate patient transfer skill, a checklist based on the required skills and wheelchair settings of nurse was adopted (Table 1). Checklist items were developed from pre-work [30], nursing materials [42–51], and discussion with experienced nursing teachers. Thus, the proposed checklist is a reliable way to evaluate the student's skill. The checklists for the pre- and post-tests were the same in order to measure learning effectiveness before and after practice; the transfer test checklist was designed with checkpoints including similar and dissimilar skills in order to observe the learning transfer of those skills, which are introduced in the next section.

As shown in Table 1, in the pre-test and post-test, there were 25 checkpoints for Type I patients and 24 for Type II patients. In the transfer test, there were six checkpoints requiring similar or dissimilar skills for Groups A and B to deal with Type III patients and four checkpoints requiring dissimilar skills in handling Type IV patients, as shown in Table 2. All the different checkpoints represent the skills required to handle the corresponding patient symptoms and conditions.

Using the checklist, the videos recorded in the pre-test, post-test, and transfer test were viewed and evaluated by a nursing teacher with more than 10 years' experience. In order to prevent bias during the pre-test and post-test, a single-blind skill evaluation was conducted, in which the teacher could not know to which group or test the recorded student belonged. In addition, to precisely evaluate and check every step of the trainee's performance, the videos could be paused and replayed.

To assess skill performance, the nursing teacher marked the student's performance of each checkpoint 'right' or 'wrong.' To measure learning effectiveness, the number of checkpoints assessed as 'right' on the pre-test and post-test were analyzed. To observe practice's effect on similar and dissimilar skills, Group A and B checklists for the transfer test were compared.

Table 1. Checklists for pre-test and post-test and results for different groups[a].

		Group A		
	Description of checkpoint for injured left arm with painful sensation and expression (Type I)	*Pre-test*[b]	*Post-test*	*Difference*
⇧ I-1	Place the wheelchair at the bedside and adjust the angle to 20–30 degrees	1	4	+3
I-2	Place the wheelchair near the patient	4	4	0
I-3	Apply the wheelchair brakes	4	4	0
⇧ I-4	Place one of your feet behind you	2	4	+2
⇧ I-5	Place your other foot between the feet of the patient	2	4	+2
⇧ I-6	Grip the bottom of the patient	0	4	+4
⇧ I-7	Make the patient sit on the edge of the bed by shuffling the patient's bottom	1	4	+3
⇩ I-8	Adjust the patient's leg and ankle posture	0	1	+1
I-9	Slowly assist and support the patient when hugging mutually	4	4	0
⇧ I-10	Avoid putting too much strain on the injured arm	3	4	+1
⇩ I-11	Place both of the patient's arms on your shoulders	4	2	−2
I-12	Grip the lower back of the patient	4	4	0
⇧ I-13	Place your right foot behind you	3	4	+1
⇧ I-14	Place your left foot between the feet of the patient	3	4	+1
⇧ I-15	Squat down and lower your waist in order to prepare the patient to stand up	0	3	+3
⇧ I-16	Make the patient lean down, and then assist the patient in standing up	0	3	+3
⇧ I-17	Use your left foot as a pivot axis to help the patient turn toward the wheelchair	3	4	+1
⇩ I-18	Lower your waist in order to prepare to assist the patient to sit down	0	0	0
⇩ I-19	Make the patient lean down and assist the patient in sitting down	0	0	0
⇧ I-20	Stand at the back of the wheelchair and place both the patient's arms in front	3	4	+1
⇩ I-21	Slowly assist and support the patient when moving the injured arm	1	1	0
I-22	Avoid putting too much strain on the injured arm	2	2	0
⇩ I-23	Make the patient sit in the wheelchair by pulling with both arms	1	1	0
I-24	Open the footrests of the wheelchair	4	4	0
I-25	Place the patient's feet on the wheelchair's footrests	4	4	0

		Group B		
	Description of checkpoint for right hemiplegia (Type II)	*Pre-test*	*Post-test*	*Difference*
II-1	Place the wheelchair on the non-paralyzed side	4	4	0
II-2	Place the wheelchair at the bedside and adjust the angle to 20–30 degrees	4	4	0
⇧ II-3	Place the wheelchair near the patient	2	3	+1
II-4	Apply the wheelchair brakes	4	4	0
⇧ II-5	Keep supporting the patient's trunk to prevent it from falling down	3	4	+1
⇧ II-6	Place one of your feet behind you	0	4	+4
⇧ II-7	Place your other foot between the feet of the patient	0	4	+4
⇧ II-8	Grip the bottom of the patient	0	3	+3
⇧ II-9	Make the patient sit on the edge of the bed by shuffling the patient's bottom	0	3	+3
⇧ II-10	Adjust the patient's leg and ankle posture	0	4	+4
II-11	Place both of the patient's arms on your shoulders	4	4	0
II-12	Grip the lower back of the patient	4	4	0
⇧ II-13	Place your right foot behind you	3	4	+1
⇧ II-14	Place your left foot between the feet of the patient	3	4	+1
II-15	Squat down and lower your waist in order to prepare the patient to stand up	1	2	+1
⇩ II-16	Make the patient lean down, and then assist the patient in standing up	0	1	+1
II-17	Assist the patient in standing up using the non-paralyzed leg	2	2	0
II-18	Use your left foot as a pivot axis to help the patient turn toward the wheelchair and use the patient's left (non-paralyzed) leg to support the patient's weight	1	2	+1
⇩ II-19	Lower your waist in order to prepare to assist the patient in sitting down	2	1	−1
⇩ II-20	Make the patient lean down, and assist the patient in sitting down	1	1	0
⇧ II-21	Stand at the back of wheelchair and place the patient's arms in front	2	3	+1
⇩ II-22	Make the patient sit in the wheelchair by pulling with both arms	0	1	+1
II-23	Open the footrests of the wheelchair	4	4	0
II-24	Place the patient's feet on the wheelchair's footrests	4	4	0

[a]The number of trainees in each group was four.
[b]This number indicates the total number of trainees who performed this item correctly.
⇧ Represents an improved checkpoint carried out by more than half of the students.
⇩ Represents a checkpoint carried out by less than half of the students.

4.4.2. *Learning transfer of similar and dissimilar skills*

The checkpoints for the transfer test covered different areas, including skills related to injured limbs, hemiplegia, and intravenous lines. These skills were similar or dissimilar skills for Groups A and B, depending on practice. Similar skills were used to handle patients who suffer from symptoms related to the students' practice but with different affected sides or body parts. This assumed that skills practiced beforehand would be adapted when used on a different patient during the transfer test. In contrast, dissimilar skills were utilized during transfer tests in which students were faced with patient situations that they had not practiced before, that is, that were unrelated to their practice experience.

Table 2. Checklist result at transfer-test.

	Description of checkpoint for left hemiplegia affecting injured right leg with painful sensation and expression (Type III)	Group A[a] No.1	Group A No.2	Group A No.3	Group A No.4	Group B[a] No.1	Group B No.2	Group B No.3	Group B No.4
▲III-1	Slowly assist and support the patient when moving the injured leg	Y[b]	N[b]	Y	Y	N	N	N	Y
▲III-2	Avoid putting too much strain on the injured leg	Y	Y	Y	Y	Y	Y	Y	Y
	Total number of skills carried out correctly:	*2*	*1*	*2*	*2*	*1*	*1*	*2*	*2*
* III-3	Place the wheelchair on the right (non-paralyzed) side	Y	Y	Y	Y	Y	Y	Y	N
* III-4	Keep supporting the patient's trunk to prevent it from falling down	N	N	N	N	Y	Y	Y	Y
* III-5	Assist the patient to stand up using the non-paralyzed leg	N	N	N	N	Y	Y	N	Y
* III-6	Use your right foot as a pivot axis to help the patient turn to the wheelchair and use the patient's right (non-paralyzed) leg to support the patient's weight	Y	Y	Y	N	Y	Y	N	Y
	Total number of skills carried out correctly:	*2*	*2*	*2*	*1*	*4*	*4*	*2*	*3*

	Description of checkpoint for intravenous line (Type IV)	Group A No.1	Group A No.2	Group A No.3	Group A No.4	Group B No.1	Group B No.2	Group B No.3	Group B No.4
⋆IV-1	Place the wheelchair to the side of the drip infusion stand	Y	N	N	N	N	N	N	Y
⋆IV-2	Move the drip infusion from the stand to the wheelchair	Y	Y	Y	Y	Y	Y	Y	Y
⋆IV-3	The drip infusion should be placed in the wheelchair on the side where the patient is equipped with the drip infusion	N	N	N	N	N	N	N	N
⋆IV-4	Clear obstacles between the bed and wheelchair and avoid any interference	N	N	N	N	N	N	N	N
	Total number of skills carried out correctly:	*2*	*1*	*1*	*1*	*1*	*1*	*1*	*2*

[a]The number of trainees in each group was 4.
[b]'Y' indicates the trainees who performed correctly; while 'N' indicates the trainees who performed incorrectly.
▲Represents checkpoints using similar skills for Group A, dissimilar skills for Group B *represents dissimilar skills for Group A, similar skills for Group B ⋆ represents dissimilar skills for Groups A and B.

4.4.2.1. Skills related to injured limbs. For the students in Group A, skills related to handling the injured leg of the Type III patient were similar skills, because they had practiced with a robot patient with an injured arm who required those skills. These similar skills were captured in the transfer test by checkpoints III-1 and III-2 in Table 2: 'Slowly assist and support the patient when moving the injured leg' and 'Avoid putting too much strain on the injured leg.' In contrast, skills related to injured limbs were dissimilar skills for Group B.

4.4.2.2. Skills related to hemiplegia. The students in Group B had learned how to deal with right hemiplegia during practice; therefore, skills presented in checkpoints III-3 to III-6 for the Type III patient were similar skills for them: 'Place the wheelchair on the right (non-paralyzed) side,' 'Keep supporting the patient's trunk to prevent it from falling down toward the left side,' 'Assist the patient in standing up using the non-paralyzed leg,' and 'Use your right foot as a pivot axis to help the patient turn toward the wheelchair and use the patient's right (non-paralyzed) leg to support the patient's weight.' Compared with the post-test checkpoints, these differ due to a difference in the paralyzed side and were adapted for the transfer test, for example, by changing the side the wheelchair was placed on and the direction of the pivot turn. In contrast, skills related to hemiplegia were dissimilar skills to Group A, because their practice involved a patient's injured arm, which is not related to hemiplegia.

4.4.2.3. Skills related to intravenous lines. The skills needed to deal with the intravenous line in Type IV patients were dissimilar skills to both Groups A and B, because the practice symptoms were not related to the intravenous line. Those dissimilar skills are described as checkpoints IV-1 to IV-4 for the Type IV patient: 'Place the wheelchair to the side of the drip infusion stand,' 'Move the drip infusion from the stand to the wheelchair,' 'The drip infusion should be placed in the wheelchair on the side on which the patient is equipped with the drip infusion,' and 'Clear obstacles between the bed and wheelchair and avoid any interference.'

4.5. Hypotheses on learning effectiveness and learning transfer

In this study, learning effectiveness with the robot was measured in advance; if learning effectiveness was observed after practice, further analysis of learning transfer was conducted. A corresponding null/alternative hypothesis of learning effectiveness is raised as follows.

$H1_{null}$: Practice has no effect on learning acquisition; therefore, there is no significant difference in performance of checkpoints I and II between the pre-test and post-test.

$H1_{alternative}$: Practice has a positive effect on learning acquisition. Therefore, there is a significant difference in performance of checkpoints I and II between the pre-test and post-test, and the performance on the post-test is superior to that on the pre-test.

This study aims to observe the effect of practice on similar and dissimilar skills. Based on a previous study [35,36], practice was understood to be transferrable to similar skills, while such learning transfer is difficult for dissimilar skills. In this light, Group A was expected to perform better than Group B on checkpoints III-1 and III-2 of Type III patients, related to skills with injured limbs, because those are similar skills for Group A and learning transfer should occur, while in contrast, the skills covered by those checkpoints are dissimilar skills for Group B. Therefore, the following null hypothesis was set.

$H2_{null}$: Practice has no effect on learning transfer to similar skills. Thus, there is no significant difference in performance of checkpoints III-1 and III-2, related to painful sensations, between Group A and B on the transfer test.

$H2_{alternative}$: Practice has a positive effect on learning transfer to similar skills. Thus, there is a significant difference in performance of checkpoints III-1 and III-2, related to painful sensations, and the performance of Group A is superior to that of Group B on the transfer test.

Making the same assumption for checkpoints III-3 to III-6, related to the hemiplegia of Type III patients, Group B is now expected to have better performance because those checkpoints are similar skills for them, so their practice with left hemiplegia can be transferred. However, for Group A, those checkpoints are dissimilar skills, and transfer might be difficult. Therefore, the following hypothesis was set.

$H3_{null}$: Practice has no effect on learning transfer to similar skills. Thus, there is no significant difference in the performance of checkpoints III-3 and III-6, related to hemiplegia, between Group A and B on the transfer test.

$H3_{alternative}$: Practice has a positive effect on learning transfer to similar skills. Thus, there is a significant difference in performance of checkpoints III-3 to III-6, related to hemiplegia, and the performance of Group B is superior to that of Group A on the transfer test.

As for Type IV patients, there were four checkpoints related to intravenous line skills representing dissimilar skills for both Group A and Group B because neither group had practiced with a Type IV patient before, and their practice had not been not related to intravenous lines. Therefore, no significant difference between Groups A and B was expected on those checkpoints, and the following hypothesis was set.

$H4_{null}$: Practice has no effect on learning transfer to dissimilar skills. Thus, there is no significant difference in performance of checkpoints IV-1 and IV-4, related to intravenous lines, between Group A and B on the transfer test.

$H4_{alternative}$: Practice has an effect on learning transfer to dissimilar skills. Thus, there is a significant difference in performance of checkpoints IV-1 to IV-4, related to intravenous lines, between Groups A and B on the transfer test.

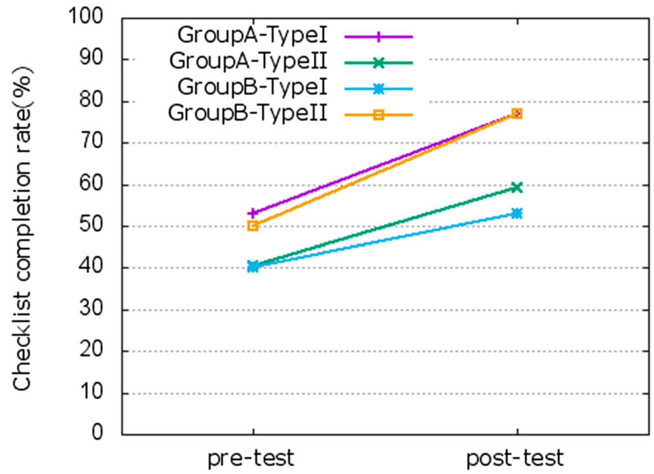

Figure 6. Learning effectiveness of pre-test and post-test.

4.6. Experiment results

4.6.1. Learning effectiveness

Detailed results of the pre- and post- tests are shown in Table 1. To investigate leaning effectiveness after training with the robot, completion ratios for the checklist, seen in Figure 6, were considered. A three-factor mixed-design analysis of variance with one between-participants factor and two within-participant factors was employed. The between-participants factor was the practice (patient) type of Group A or B, each consisting of four students. One of the within-participant factors was learning effectiveness: pre-/post-test; the other was the tested patient type: injured left arm with painful sensation and expression/right hemiplegia. For the calculation, the input data is the total number of correct skills performed by each student.

$H1_{null}$ was rejected, and $H1_{alternative}$ was accepted, because a significant difference in learning effectiveness was found ($F(1,6) = 32.50$, $p = 0.001$). There were no significant differences by practice patient type or tested patient type ($F(1,6) = 0.45$, $p = 0.529$, $F(1,6) = 0.04$, $p = 0.844$, respectively). In addition, we found a significant interaction between practicing patient type and tested patient type ($F(1,6) = 10.39$, $p = 0.018$), practicing patient type and learning effectiveness ($F(1,6) = 0.03$, $p = 0.860$), learning effectiveness and the tested patient type ($F(1,6) = 0.72$, $p =$

0.429), or among the three factors ($F(1,6) = 3.45$, $p = 0.113$). Simple effects of the interaction between the practicing patient type and the tested patient type were as follows: under the test for the patient robot with injured left arm ($F(1,6) = 19.84$, $p = 0.004$) and with right hemiplegia ($F(1,6) = 3.07$, $p = 0.130$), significant difference and no difference of the practicing patient type, respectively; no significant differences of the tested patient type under the practicing robot with the injured left arm ($F(1,6) = 3.39$, $p = 0.163$) or with right hemiplegia ($F(1,6) = 8.95$, $p = 0.058$).

4.6.2. Practice effects on the learning transfer of similar and dissimilar skills

The results of the transfer test are presented in Table 2. The Mann–Whitney U-test was employed to investigate differences between Groups A and B. The between factor is set as the group, and each group includes four students. During the calculation, the input data is the total number of correct skills the student performed.

4.6.2.1. Skills related to injured limbs: similar skills in Group A vs. dissimilar skills in Group B. In the Type III patient transfer test, checkpoints III-1 and III-2 required skills related to injured limbs – similar skills for Group A and dissimilar skills for Group B. Checkpoint III-1 was carried out by three students in Group A, but no student in Group B executed it successfully. As for checkpoint III-2, all four students in each group carried it out. There was no significant difference between Groups A and B ($p = 0.608$); therefore, $H2_{null}$ is accepted, showing that practice related to an injured arm does not cause a significant effect. Potential reasons for these results are presented in the discussion.

4.6.2.2. Skills related to hemiplegia: dissimilar skills in Group A vs. similar skills in Group B. Regarding checkpoint III-3, four students in Group A and three students in Group B successfully executed this skill. For checkpoint III-4, no student in Group A carried it out, but all students in Group B did. As for checkpoint III-5, no student in Group A executed it correctly, while three students in Group B did. For the last checkpoint, III-6, both groups had three students who completed it successfully. We found a significant difference between Groups A and B ($p = 0.044$); thus, the null hypothesis is false and $H3_{alternative}$ is accepted. Also, the result shows that practicing right hemiplegia skills leads to better performance on checkpoints related to left hemiplegia.

4.6.2.3. Skills related to IV: dissimilar skills in Groups A and B. To handle the Type IV patient transfer test, checkpoints IV-1 to IV-4 required skills that neither group had previously learned, that is, where there was no similarity with their simulation practice. Checkpoints IV-1 was carried out by only one student in each group, and no students successfully completed checkpoints IV-3 and IV-4. These overall low numbers entail no significant difference between groups ($p = 1.000$). Thus, $H4_{null}$ is true and accepted ($p > 0.05$) for checkpoints IV-1 to IV-4, showing no significant difference between groups for skills related to intravenous lines.

5. Discussion

5.1. Learning effectiveness in the post-test

The pre- and post-test results reveal that practicing with the robot patient contributes to learning effectiveness. In Group A, 12 checkpoints (I-1, I-4 to I-7, I-10, I-13 to I-17, and I-20) related to transferring the patient with injured left arm improved and were carried out by half of the students or more. In Group B, 10 checkpoints (II-3, II-5 to II-10, II-13, II-14, and II-21) were improved for right hemiplegia. These significant improvements in skill performance show that the robot's simulation of patient behavior helps students learn the corresponding skills for those checkpoints. For example, the ability of the robot's waist and hip joint hardware to imitate trunk instability allows the student to acquire the skill of supporting the trunk of a hemiplegia patient, while the robot's pain sensing and expression functions enable students to learn how to gently assist the patient without causing pain. Those results reveal that by employing the robot patient for practice, patient transfer skill learning effectiveness can be obtained. This is consistent with the conclusion of a previous study, which found that practicing with simulators enhanced the learning of nursing skills [30]. In addition, the robot patient was developed with 18 DoFs, which is fewer than those of an actual human, but it is enough for training transfer skills because robot patient DoFs are determined by the movements involved during the transfer processes. Furthermore, even though differences exist between the robots and humans, such as physical appearance, DoFs, and the structure mentioned in Huang et al. [31], learning effectiveness still enables the learners to obtain skills, revealing the applicability of robot simulation in nursing education.

However, there were still some checkpoints only carried out by less than half of the students. Examples include 'Lower your waist in order to prepare patient to stand up/sit down' and 'Make the patient lean down and assist the patient in standing up/sitting down.' These skills can help nurses avoid lumbar injuries and help them assist patients in standing up and sitting down more smoothly [43], while novice or unskilled students may find it hard to obtain these skills.

In addition, 'Adjust the patient's leg and ankle posture' and 'Make the patient sit in the wheelchair by pulling with both arms' were carried out by less than half the students. These two checkpoints asked the students to conduct posture adjustment on the patient, but if the posture of the patient was already correct, then the student did not need these skills.

Checkpoint I-21 for the Type I patient, 'Slowly assist and support the patient when moving the injured arm,' performed while the patient is sitting in the wheelchair, was carried out by only one student in Group A, because the robot patient's injured arm, which did not exert any force from the motors, tended to fall down off the student nurse's shoulder accidently, leading the nursing teacher to evaluate the attempt as 'wrong.' However, skills related to treating the injured arm gently were learned by the students, as can be observed in checkpoint I-9, which all the students executed well.

This study measured learning effectiveness right after practice; examining immediate retention enables direct observation of the effect of practice, as shown in other studies [44]. While some previous studies measured prolonged retention [45], that involves other potentially affecting factors such as memory or self-learning, which are not immediately relevant. Prolonged retention is an area we intend to investigate in the future.

A significant difference between pre- and post-tests were found for the tested robot with right hemiplegia in Group A and for the tested robot with an injured left arm in Group B, though the injured left arm scores in Group B were lower than those in Group A under both pre- and post-tests. Although these results seem to reveal the existence of learning transfer, a potential effect of the pre-test with a different patient type from the practice type cannot be excluded. In the next session, we will discuss the results of the transfer test.

5.2. Learning transfer in the transfer test

5.2.1. Skills related to injured limbs: similar skills in Group A vs. dissimilar skills in Group B

According to the results for checkpoints III-1 and III-2, a high completion rate on similar skills related to the injured arm was obtained from Group A, which showed significant learning transfer. However, in Group B, most students could also execute those checkpoints, showing that learning transfer of dissimilar skills also occurs, contrary to H2. Why were dissimilar skills carried forward by the students in Group B, who did not practice with symptoms related to injured limbs? One reason may be that dissimilar skills related to injured limbs are common and familiar to nursing students, allowing them to be easily generated. In nursing education, to increase the comfort of patients, pain management is widely taught as basic skills and knowledge [46–48]. Thus, even student nurses are generally able to employ the correct gentle, careful way of treating these limbs, even if they have not practiced with real or simulated patients suffering from injured limbs. Another potential reason may due to the 'it hurts' utterance generated by the robot. This feedback on the patient's sensations allows the nursing student to understand the perceptions of the patient and employ the proper manner of care. This is also consistent with a previous study [49] stating that feedback facilitates the performance of skills. Thus, even though students did not practice with injured limb symptoms, the dissimilar skill of caring for an injured limb could be carried out.

5.2.2. Skills related to hemiplegia: dissimilar skills in Group A vs. similar skills in Group B

According to the Mann–Whitney test results shown in Table 2, Group B performed better than Group A on the checkpoints related to hemiplegia. This result is consistent with the hypothesis that learning transfers to similar skills better than dissimilar skills. This leads to the same conclusion as shown in Schilling et al. and Thrun and Lorien [35,36], of the importance of introducing a learning method that transfers knowledge across learning tasks based on task similarity. However, distinct from the discussion in the previous section, which suggested that the correct skills to treat injured limbs can be developed by students who have not had related practice, in this case, it seems that dissimilar skills related to hemiplegia cannot be learned if there is no related practice. This may be because nursing students are generally unfamiliar with hemiplegia, and there is little access to hemiplegia patients in school [50]. Therefore, the Group A students, with no related practice or knowledge, would have found it difficult to support the paralyzed trunk. These differences in learning transfer results for dissimilar skills involving unfamiliar symptoms are important information for training and curriculum design in nursing education: for dissimilar skills that are difficult to transfer from practice, simulated targeted training at schools should be enhanced, or students will be incapable of applying those skills when needed in their future careers. As in previous studies, most simulation-training robots have been developed to reproduce symptoms that students have little access to in actual patients, such as rigidity or spasticity [20,21]. Furthermore, some symptoms are difficult for healthy individuals serving as training partners in simulations to reproduce. For example, healthy individuals may find it difficult to imitate paralyzed patients, because they unconsciously exert force to support their own body. In this respect, using a simulator or robot in simulated training provides an advantage.

However, some checkpoints did not reveal a significant difference between groups. For example, in. checkpoints III-3 and III-6, both groups carried out the task at a high level. That is, students in Group A were still able to execute these skills related to hemiplegia, despite their lack of experience. This could be explained by the fact that all the participants had already learned the basic skills of patient transfer (as the experimental participants in this study were limited to students with this background), including that the wheelchair should be placed on the patient's stronger or healthier side, and that they should use this side to execute pivot turns during patient transfer [51].

5.2.3. Skills related to intravenous lines: dissimilar skills in Groups A and B

For the Type IV patient, the results exhibited a low completion rate and no significant difference between Groups A and B. This could be because the different unrelated practice undergone by Group A and Group B did not affect learning transfer toward intravenous line skills in either case. This may be interpreted to show that dissimilar skills used to deal with new conditions are difficult for students to execute if they did not learn them previously, supporting H4.

6. Conclusion and future work

This research aimed to evaluate the effect of practice on the learning transfer of the similar and dissimilar skills used to handle different types of patients, and in so doing, to discover what types of symptoms can be effectively trained in simulation using the proposed robot. An experiment was conducted with nursing students in two groups with different types of patients. Pre- and post-tests were employed to examine the robot's learning effectiveness, and a transfer test was conducted to observe learning transfer for similar and dissimilar skills. All the transfer trials of students in pre- and post- tests were assessed by an experienced nursing teacher. The results can be summarized as follows:

- Learning transfer was observed for similar skills. For instance, practice with an injured arm enables transfer to skills dealing with an injured leg; practice with right hemiplegia can be transferred to left hemiplegia.
- Learning transfer was scarce for dissimilar skills. For example, practice with injured limbs did not transfer to skills with hemiplegia, nor did practice with either injured limbs or hemiplegia transfer to intravenous line skills.
- Practicing with a patient whose symptoms do not readily draw learning transfer from practice with other symptoms and also have low accessibility to nursing students, such as hemiplegia, should thus be emphasized though simulated training using the proposed robot.
- In our future studies, we will conduct experiments to observe the long-term retention of learning transfer and the potential effects of other factors. Also to measure whether simulation learning through a robot patient can be transferred to an actual patient. In addition, we also intend to increase the effectiveness of using the robot to practice other skills.

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