博士学位論文

Redefining horticultural therapy toward
integrative medicine and building its framework

近畿大学大学院

農学研究科　農業生産科学専攻

三　田　清　華

Redefining horticultural therapy for integrative medicine and building its framework　Sayaka Mita

博士学位論文

Redefining horticultural therapy toward integrative medicine and building its framework

2022 年　1 月　8 日

近畿大学大学院

農学研究科 農業生産科学専攻

三　田　清　華

CONTENTS

Chapter 1 | General introduction

1. 1. Horticultural therapy

1. 1. 1. History

In a broad sense, horticultural therapy (HT) means using gardens and horticulture to support people's health. It is said that it originated from a doctor prescribing a walk in the garden to a royal family with mental disorders during the ancient Egyptian era [1]. HT has a long history of practice, but its treatments and effects began to be scientifically studied in the 19th century.

In the 19th century, horticulture was used in the United States for mental health care for children and adults with mental illness. Since World War II, horticulture has been used in hospitals as a treatment to improve the mental and physical functions of patients and veterans. Dr. Benjamin Rush, known as the "father of American psychiatry," was the first to report that garden activity programs had a positive impact on human health.

From the 1940s to the 1950s, the practice of HT was promoted as rehabilitative care for veterans in the United States. As HT became more popular in society, the purposes of garden-based treatments diversified into human mental health care, rehabilitation, vocational training, and community acquisition [1].

In 1960, HT-related lectures began at a university in the United States. In 1973, the American Horticultural Therapy Association (AHTA) was established and a horticultural therapist qualification system was born. In 1978, HT became recognized in the United Kingdom, and that year the Horticultural Therapy and Rural Training Association (H.T.) was established.

In Japan, HT was popularized in early 1990 by experts who learned HT in the United States and citizens who were highly interested in HT [2]. The study of HT was introduced to Japan by Dr. Eisuke Matsuo of Kyushu University.

1. 1. 2. Definition

HT is often confused with therapeutic horticulture (TH), social horticulture (SH), and vocational horticulture (VH). To prevent the misrecognition of HT, they are defined by AHTA as follows [3].

- "Horticultural therapy is the engagement of a patient in horticultural activities facilitated by a trained therapist to achieve specific and documented treatment goals. AHTA believes that horticultural therapy is an active process which occurs in the context of an established treatment plan where the process itself is considered the therapeutic activity rather than the end product. Horticultural therapy programs can be found in a wide variety of healthcare, rehabilitative, and residential settings."

- "Therapeutic horticulture is a process that uses plants and plant-related activities through which participants strive to improve their well-being through active or passive involvement. In a therapeutic horticulture program, goals are not clinically defined and documented but the leader will have training in the use of horticulture as a medium for human well-being. This type of program may be found in a wide variety of healthcare, rehabilitative, and residential settings."

- "Social horticulture, sometimes referred to as community horticulture, is a leisure or recreational activity related to plants and gardening. No treatment goals are defined, no therapist is present, and the focus is on social interaction and horticulture activities. A typical community garden or garden club is a good example of a social horticulture setting."

- "A vocational horticulture program, which is often a major component of a horticultural therapy program, focuses on providing training that enables individuals to work in the horticulture industry professionally, either independently or semi-independently. These individuals may or may not have some type of disability. Vocational horticultural programs may be found in schools, residential facilities, or rehabilitation facilities, among others."

Table 1 summarizes the main points of these definitions (Table 1). These classifications are mainly based on five criteria: (1) Whether there are documented treatment goals, (2) Whether it is practiced by a professionally trained therapist, (3) Whether there is a treatment plan, (4) Whether an HT program is used, and (5) The purpose of use is either healthcare, recreation, or training.

In many cases, the definition of HT does not explain its essence. The essence of HT is why plants are the medium of treatment. In other words, it is a value that cannot be replaced by other CAMs.

Horticultural therapists are learning the essence of HT from their clinical experience. Horticultural therapists are professionally trained individuals who practice HT safely and effectively. The purpose of HT is broad, including health care for cognitive and physical functions, as well as sociality. Therefore, the treatment targets are wide-ranging, including patients with mental illness, schizophrenia, or dementia, as well as frail elderly people. Most horticultural therapists uniquely interpret the essence of HT and optimize treatment in the process of practicing HT for a variety of purposes and patients. Thus, the treatment method differs depending on the experience and knowledge of the horticultural therapist.

The definition of HT, whose essence is not uniquely understood, also prevents horticultural therapists from establishing themselves as a profession. In South Korea, horticultural welfare activities performed by people who do not have specialized training in HT are sometimes called HT [4]. The reason for this is the misconception that a person can benefit from therapeutic effects of HT if a person is simply involved in gardening and horticulture. Such social conditions reduce the quality of HT and the professional value of horticultural therapists. In order for the value of HT and horticultural therapists to be socially recognized, it should be redefined so that the essence of HT can be uniquely understood.

Table 1. Classification of horticultural therapy, therapeutic horticulture, social horticulture, and vocational horticulture.

	Horticultural Therapy	**Therapeutic Horticulture**	**Social Horticulture**	**Vocational Horticulture**
Specific and documented treatment goals	✓			
Horticultural therapist	✓	That depends on the situation		
An established treatment plan	✓	✓		
Horticultural therapy programs	✓	✓	✓	✓
The purpose of treatment	Healthcare	Healthcare	A leisure or recreational activity	Training

Available: With check mark
Not available: No check mark

1. 1. 3. Qualifications of a horticultural therapist

Horticultural therapists are professionals who are educated and trained in practicing HT. In the United States, the qualification of a horticultural therapist is accredited by the AHTA. In Japan, horticultural therapists are certified by four organizations: Japan Association University and College for Business Education, Japan Horticultural Therapy Association, Awaji Landscape Planning & Horticulture Academy, and Japan Society for Therapists of Horticulture.

To qualify, a horticultural therapist must have knowledge and skills in the principles of horticulture, botanical science, human science, medical welfare, and horticultural therapy. In addition, horticultural therapists need to acquire practical skills through HT training and exercises.

The AHTA criteria for specific conditions for obtaining that qualification are introduced below [5].

（1）"Has a minimum of a bachelor’s degree in horticultural therapy, or the minimum of a bachelor’s degree with additional coursework in plant science, human science, and horticultural therapy."

（2）"Has completed a 480-hour internship in horticultural therapy."

（3）"Is professionally registered as a horticultural therapist with the American Horticultural Therapy Association as an HTR, Horticultural Therapist-Registered."

1. 1. 4. Treatment approach

Treatment of HT is practiced using gardens and HT programs. The garden used for treatment is called a healing garden. Healing gardens are not strictly defined, but AHTA explains [3]:

(a) Types of healing gardens

- Healing Gardens: "Healing gardens are plant dominated environments including green plants, flowers, water, and other aspects of nature. They are generally associated with hospitals and other healthcare settings, designated as healing gardens by the facility, accessible to all, and designed to have beneficial effects on most users. A healing garden is designed as a retreat and a place of respite for patients, visitors, and staff and to be used at their desire. Healing gardens may be further divided into specific types of gardens including therapeutic gardens, horticultural therapy gardens, and restorative gardens. These garden types are likely to have overlap and the following definitions should be regarded as guidelines since no two gardens are the same."

- Therapeutic Gardens: "A therapeutic garden is designed for use as a component of a treatment program such as occupational therapy, physical therapy, or horticultural therapy programs and can be considered as a subcategory of a healing garden. A garden can be described as being therapeutic in nature when it has been designed to meet the needs of a specific user or population. It is designed to accommodate patient treatment goals and may provide for both horticultural and non-horticultural activities. It should be designed as part of a multi-disciplinary collaborative process by a team of professionals. A therapeutic garden may exist on its own as an extension of an indoor therapeutic program area or it may be part of a larger healing garden."

- Horticultural Therapy Gardens: "A horticultural therapy garden is a type of therapeutic garden; it is designed to accommodate patient treatment goals, but it is designed to support primarily horticultural activities. A horticultural therapy garden is also designed in such a manner that the patients themselves are able to take care of plant material in the garden."

- Restorative Gardens: "A restoration or meditation garden may be a public or private garden that is not necessarily associated with a healthcare setting. This type of garden employs the restorative value of nature to provide an environment conducive to mental repose, stress-reduction, emotional recovery, and the enhancement of mental and physical energy. The design of a restorative garden focuses on the psychological, physical, and social needs of the users."

In HT, healing gardens are used to help horticultural therapists practice the HT program. The HT program will be discussed in more detail in the next section, but its content focuses on plant cultivation. For example, in the healing garden, handrails and slopes are designed so that people with disabilities can grow plants. Its design is primarily handled by landscaping experts. At that time, the horticultural therapist may give advice on the type and arrangement of plants, but rarely takes charge of the design itself. Therefore, the main role of horticultural therapists is in the design and practice of HT programs. In this paper, the design and practice of the HT program was treated as a treatment.

(b) Horticultural therapy program

Treatment with an HT program is characterized by its slow-acting effects and the need for long-term intervention. An HT program is a treatment plan that combines multiple horticultural tasks. These tasks are broadly divided into six categories: (1) plant sowing, (2) seedling raising, (3) seedling transplantation, (4) management (irrigation / weeding), (5) flower and fruit harvesting, and (6) activities using harvested products. Horticultural therapists generally develop treatment plans that combine these tasks according to the patient's health condition and the HT practice environment.

A patient's health status includes mental, physical function, and palatability. A patient's health status changes daily depending on aging, illness, and mood. Therefore, in clinical practice, a horticultural therapist may change the design of the horticultural task according to the health condition of the patient. For example, in an HT program for elderly people with weak muscles, PET bottles containing 500 mL of water are used instead of watering cans containing 5 L of water when watering plants. This can reduce the burden on the patient's arm during work. Also, some patients are in wheelchairs and cannot bend or stretch their legs. In that case, the activity of sowing plant seeds is designed such that seeds are sown in a cell tray on a desk instead of directly in a field. For patients who do not like to touch soil and insects, activities such as cooking with harvested vegetables and herbs may be planned.

The reason horticultural therapists consider the HT practice environment is to select the types of plants that can be used for horticultural tasks. The key to successful plant cultivation is to select the most suitable type and variety for environmental conditions such as light intensity, sunshine duration, temperature, humidity, soil structure, water quality, and fertilizer type. Their environmental conditions vary by country / region, season, and outdoor or indoor environments. Therefore, the horticultural therapist selects the type and variety of plants to be cultivated according to the practical environment of the HT.

Basically, plants with poisons and thorns, plants that can cause allergic symptoms in patients, and plants that are difficult to cultivate are not selected. On the other hand, plants that produce vegetables and flowers, plants that have aromatic components that improve the mindset of patients, and plants that are relatively easy to cultivate are preferred. For example, in Japan, tomatoes and cucumbers are relatively easy to cultivate during the summer, so these plants are often selected.

1. 1. 5. Treatment effects

The effects of HT programs have been evaluated by various researchers, but there is a gap between clinical and research evaluations. It may be due to the fact that the practice method of HT programs differs between clinical and research sites.

In clinical practice, an HT program is practiced on the premise that the horticultural therapist adjusts the content of the horticultural task according to the patient's individual illness and mental and physical conditions. On the other hand, in the research field, the effect is verified by a comparative experiment excluding that premise.

Previous studies have investigated the effects of HT programs designed for mental illness [6, 7], schizophrenia [8, 9], dementia [10-12], and frail elderly [13]. It has been suggested that the HT program for schizophrenia can improve symptoms [9]. The HT program for dementia has been suggested to be effective in reducing cognitive decline [12]. The HT program for the frail elderly has also been reported to promote physical activity and community participation [13]. These findings suggest that HT programs have a positive effect on the patient's mental, cognitive, and physical activity. However, some studies point out that HT studies have inconsistent therapeutic interventions, study designs, and analytical methods that require the accumulation of scientific evidence through higher quality studies [14]. Previous studies have suggested that the effect of an HT program depends on the type of horticultural work [15].

The effect of an HT program observed in clinical practice may be produced by the technique of modifying the content of the horticultural task by the horticultural therapist. It may be important to scientifically clarify the role and effectiveness of the technology.

1. 2. Western medicine

1. 2. 1. Development of Western Medicine

WM is a medical system for removing lesions and reducing pain in patients by using means such as medication, surgery, and radiation. The characteristics of the treatment are that the effect is immediate and the treatment period is short.

WM originated in medieval Europe. At that time, the Hippocrates of Kos, called the "Father of Medicine," thought that the human body was made up of four liquid containers [16]. Later, other prominent doctors and scholars revealed that the cause of disease was bacteria and microorganisms, and a modern "epidemiological" concept was constructed [16]. During the 18th century, the concept of health and illness was developed from an "anatomical" or "physiological" perspective with the development of culture [16]. Its "anatomical" scope includes organs, components and specific components of organ tissues, and cells.

In the 19th century, the idea of health and illness was pursued based on anatomical and physiological studies. French philosopher and physiologist Claude Bernard elaborated on the concept of the "internal environment" (*milieu interieur*) of living things, which later led to an understanding of human homeostasis [16].

During the 20th century, research on normal cells and pathological cells progressed, and the pursuit of knowledge at the molecular level is progressing [16]. The development of medical technology based on reductionism, the results of biomedical and clinical research, and the improvement of disease management ability have brought about a change in treatments in WM [17]. Disease-based approaches, evidence-based approaches, and personalized treatment-oriented approaches are known as major conceptual frameworks for these treatments [17, 18]. Through these three major paradigm shifts, the quality of WM treatment has improved. Details of each paradigm are described in the next section.

1. 2. 2. Treatment approach

(a) Disease-based approach

A disease-based approach is considered to be the oldest conceptual framework in the history of WM [17]. This approach is based on the concept of treating a patient only when the disease appears [18]. In this approach, the diagnosis of the patient's symptoms and the prescription of treatment were practiced according to the doctor's experience, knowledge, and ideas [17, 18]. However, in the early 1990s, a movement to ensure the efficacy and safety of disease-based approaches began [19]. That led to today's evidence-based approach.

(b) Evidence-based approach

The evidence-based approach is based on the notion that physicians should be conscientious, clear, discreet, and use the latest and greatest medical findings when making decisions regarding the treatment of individual patients [20]. It means that it is important to make rational decisions and plan treatment based on objective indicators, rather than practicing treatment based on the experience and ideas of doctors. To put this into practice, critical assessments and systematic reviews of patient diagnosis, treatment, and care were recommended in the medical field [17, 19]. As a result, the quality of treatment has improved and highly reproducible treatments have been developed. In addition, medical guidelines developed based on biomedicine and clinical research were used so that all physicians could provide high-quality treatments [17, 19]. This has enabled doctors to understand disease mechanisms based on medical knowledge, and to verify the optimal treatment and their therapeutic effects [17, 19]. In this way, WM showed the effectiveness and reliability of treatment by diagnosing the disease based on objective indicators and shifting to an approach to determine the treatment method.

(c) Approach aimed at personalized medicine

In recent years, it has been clarified that not only molecular and physiological factors but also living environment and individual behaviors influence the disease progression of patients [21, 22]. Personalized medicine was born from the concept that treatment should be performed according to the combined characteristics of patient-specific molecular, physiological, environmental exposure, and behaviors [21]. The approach prescribes treatment using the patient's genomic, epigenetic, and lifestyle parameters [17]. It is said that this may allow patients to receive optimal treatment for improving their health.

1. 2. 3. Limitations of mechanistic treatment approach

WM's treatment approach is based on the concept of restoring imbalances in the body caused by some disease (allopathy). For example, if you have a fever, an antipyretic is prescribed, and if you have diarrhea, an antidiarrhea medication is prescribed. Those treatment approaches view humans from a reductionist perspective. The reductionist point of view in medicine is that humans have a hierarchical structure at the organ level, cell level, and molecular level, and if the site where the disease occurs is treated, it will return to its original state. It views humans mechanistically and does not take into account the effects of human mental health.

The development of medical technology in the 20th century has extended the life expectancy of people around the world. According to data from Japan’s Ministry of Health and Welfare, the average life expectancy of Japanese people increased by about 20 years between 1950 and 2000. In 2019, the average life expectancy for men was 81.41 years and that for women was 87.45 years. The number of elderly people who develop dementia is increasing due to the increase in life expectancy [23, 24]. A treatment method for dementia has not been established, and it is required to prevent mental deterioration associated with worsening of symptoms [24].

In recent years, the number of patients with non-communicable diseases (NCDs) that cannot be completely cured by mechanistic treatment approaches that do not consider human mentality is increasing. NCD is a general term for diseases that are not transmissible, and are also called chronic diseases. The main diseases are heart disease, cancer, chronic respiratory disease, and diabetes. It is known that the symptoms of these NCDs often progress slowly. According to a 2018 study conducted by the United States, more than a quarter of adults in the United States had two or more chronic illnesses in 2012 [25]. The number has increased by 22% compared to 2001, and is estimated to increase year over year [26].

Patients in need of long-term treatment, such as non-communicable or chronic diseases, often suffer from depression and anxiety [27, 28]. Such psychological conditions increase the risk of physical morbidity and death [29] and require WM and mental health care support [30-33]. Mental health care is important for patients receiving long-term care to encourage their willingness to continue treatment. However, WM does not maintain a therapeutic approach that provides long-term care for the patient's mental health. Therefore, in recent years, there has been increasing interest in complementary and alternative medicine (CAM) that supplements the therapeutic effect that WM lacks. In addition, medical research is beginning to explore new medical systems that integrate WM and CAM.

1. 3. Complementary and alternative medicine

The National Center for Complementary and Alternative Medicine (NCCAM) defines CAM as a group of diverse medical and health care systems, practices, and products that are not presently considered to be part of conventional medicine. The "conventional medical treatment" means WM.

According to a 2008 US survey, 4 out of 10 adults in the US used CAM [34]. CAM's therapeutic approach is based on the notion that the process by which a patient recovers function involves a variety of factors and their interactions in their internal and external environments [35, 36]. In recent years, as the public health system has shown interest in providing CAM, there is an increasing need for research to understand its complex system [35].

CAM modalities are categorized by NCCAM into five categories: (1) alternative medicine systems, (2) psychosomatic interventions, (3) biologically based treatments, (4) manipulation and body-based methods, and (5) energy therapy. Counseling, exercise, massage, nutrition therapy, psychotherapy, essence stimulation, and vitamins are recognized as orthodox treatments in these categories [36]. On the other hand, acupuncture, herbal medicine, homeopathy, osteopathy, biofeedback, chiropractic, hypnosis, meditation, and natural remedies are recognized as unorthodox [36]. The HT featured in this study is also classified as one of the types of CAM.

1. 4. Expectations for integrative medicine

Integrative medicine (IM) is a medical system for treating the entire human mind and body that combines WM's mechanical treatment approach and CAM's holistic treatment approach. The definition of IM is "medicine that reaffirms the importance of the relationship between practitioner and patient, focuses on the whole person, is informed by evidence, and makes use of all appropriate therapeutic approaches, healthcare professionals, and disciplines (conventional and complementary) to achieve optimal health and healing" [37].

Previous studies have reported that the use of IM for dementia improved anxiety and depression [38-40]. It has been suggested that a combination of oral medication and HT for patients with schizophrenia is also effective in reducing anxiety [41].

The National Institute of Health and the Ministry of Health, Labor and Welfare in Japan have discussed ways to implement IM in society. However, no concrete measures have been shown and it has not been clinically disseminated.

1. 5. Problems in horticultural therapy from the perspective of integrative medicine

The combination of WM and HT may improve the mental and physical morbidity of patients seeking long-term treatment. However, the current HT cannot be combined with WM. There are two reasons.

The first is that the essence of HT is not uniquely understood and its treatment is vaguely practiced. Personalized medical treatments in WM have scientific evidence of therapeutic targets, mechanism of action, and efficacy. On the other hand, the essence of the treatment method in HT is unknown, the mechanism of action is a black box, and the scientific evidence of the effect is insufficient. Such HT cannot share accurate treatment information with WM specialists or patients who bear medical costs. In order to integrate WM and HT, it is important to clarify the mechanism of action and essence of therapies in HT. In addition, it is necessary to develop a treatment method based on the mechanism of action and scientifically verify the effect.

Second, while the therapeutic approach in WM has evolved into personalized medicine, the HT therapeutic approach is primarily a group-based program. When combined with WM personalized medicine, the HT program should be reasonably and systematically designed according to the individual's illness and physical and mental condition. In addition, although the group-based HT program has the advantage of reducing the cost of treatment per patient, personalized medicine may be effective in obtaining a higher therapeutic effect. Therefore, it is necessary to develop HT from the perspective of group-based medical care to personalized medical care and build a framework for it.

1. 6. Methodology for solving the problem

In this study, three methodologies were used to elucidate the mechanism of action of HT and to establish a framework for rational and systematic practice of its treatment: systems approach (systems thinking / system dynamics), a demonstration experiment, and the PDCA cycle.

Systems thinking is a methodology that captures a complex process consisting of various components and causal relationships between components as one system (Fig. 1) [42]. For example, a manufacturer's manager wants to know the process by which a product reaches a consumer in order to reduce manufacturing costs. When systems thinking is applied to that process, "product manufacturing" and "consumer purchasing" are positioned as subsystems. The "product manufacturing" subsystem has components such as raw material procurement and production control for products. The "consumer purchasing" subsystem has components such as logistics and products for sale. By connecting these components according to the causal relationship and time series, it becomes clear that the process is "procurement of raw materials for products → production control → distribution → sales of products." This process is commonly known as the supply chain. According to the rules of systems thinking, horticultural therapists and patients in HT can be regarded as subsystems. By extracting the components of each subsystem and the causal relationships between the components based on the findings of previous studies, I thought that it would be possible to create a system model that visually shows the mechanism of action of HT and its essence.

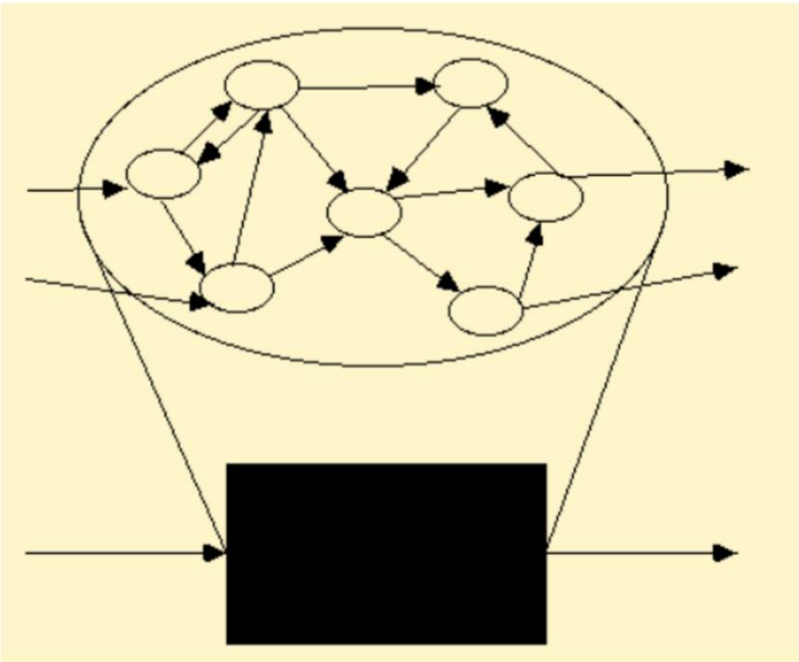

Figure 1. Partial excerpt from the Basic Concepts of the Systems Approach (F. Heylighen, 1998).

A horticultural task was devised based on the working hypothesis to provide scientific evidence of HT treatments and effects, and their effects were validated. This time, a horticultural task was devised to control delay the progression of dementia based on the HT system model. In this experiment, I tried to verify the effect of horticultural tasks by measuring the increase in cerebral blood flow as an index of cognitive function activity. In this paper, the treatment method created based on the working hypothesis in HT is defined as a horticultural task, and the horticultural task whose effect is scientifically proven is defined as a functional horticultural task.

Even if a functional horticultural task can be developed once, the reproducibility of the effect cannot be guaranteed if the horticultural therapist designs the task based on empirical data. System dynamics is the best methodology for horticultural therapists to design functional horticultural tasks based on rational decision making. It is a method developed by Jay Wright Forrester of the Massachusetts Institute of Technology. In this method, both the components shown in the system model and the causal relationships between the components are defined numerically. Thereby, the static systems model can be transformed into a dynamic model with a time axis. Here, the components of the HT system model have been modified so that personalized medicine can be performed according to the patient's disease and personality characteristics. By applying system dynamics to the system model, I thought that functional horticultural tasks and individual patient diseases and personality traits could be quantified. In addition, I use the system dynamics model to simulate different rates of functional recovery depending on the patient's disease and personality traits so that the horticultural therapist can reasonably decide on a functional horticultural task.

In clinical practice, it is necessary to practice functional horticultural tasks for a long period of more than half a year until the patient recovers. In our previous clinical trials, it was observed that the effects of functional horticultural tasks depended on the severity of dementia. For patients with dementia, it is important for the horticultural therapist to provide optimal functional horticultural tasks as their severity improves. In the fields of manufacturing, services, and education, the PDCA cycle is used as a methodology for systematically improving the quality of these services in the long term. In the PDCA cycle, P means planning, D means doing, C means checking, and A means acting. This is a project management method devised by William Edwards Deming. When the PDCA cycle is applied to HT, it is possible to construct a framework such as planning the HT program (P), providing it to the patient (D), evaluating the effect of the program (C), and improving the program (A). In P and A, horticultural therapists can use the dynamics model of HT to predict the effects of multiple horticultural tasks in advance. I tried to establish a framework for horticultural therapists to use the HT dynamics model to support decision-making rationally and to treat them in a long-term and systematic manner, such as the PDCA cycle.

The use of gears is symbolic of the problems and solutions in this study (Figure 2). The vertical axis in Figure 2 indicates whether the target of one treatment approach is a group or an individual. The horizontal axis indicates whether the therapeutic approach is mechanistic or holistic. The three therapeutic approaches in WM are cogwheels, shown in bluish colors. The size of each cogwheel indicates the speed at which the therapeutic effect occurs. In other words, the size of the cogwheel is shown to be smaller as the therapeutic effect is immediate. The cog means a treatment method in which the mechanism of action, purpose, and method are clearly defined. On the other hand, the conventional therapeutic approach in HT is indicated by a green wheel. The therapeutic approach in HT uses an HT program developed according to the patient's age and illness, but its mechanism of action is a black box, and its essence and method have been vaguely practiced. Therefore, HT was shown as a cogless wheel.

The application of systems thinking to HT is to clarify the mechanism of action of treatment and its essence and method. Developing a functional horticultural task for HT means attaching a cog to the wheel. Applying system dynamics to HT means quantifying the horticultural task effect, that is, the size of the cogwheel. As a result, the HT cogwheel can be adjusted to the size and cog pitch of the personalized medical cogwheel in WM. Furthermore, the application of the PDCA cycle to HT means to establish a dynamic framework for integrating HT and WM cogwheels for long-term and systematic treatment.

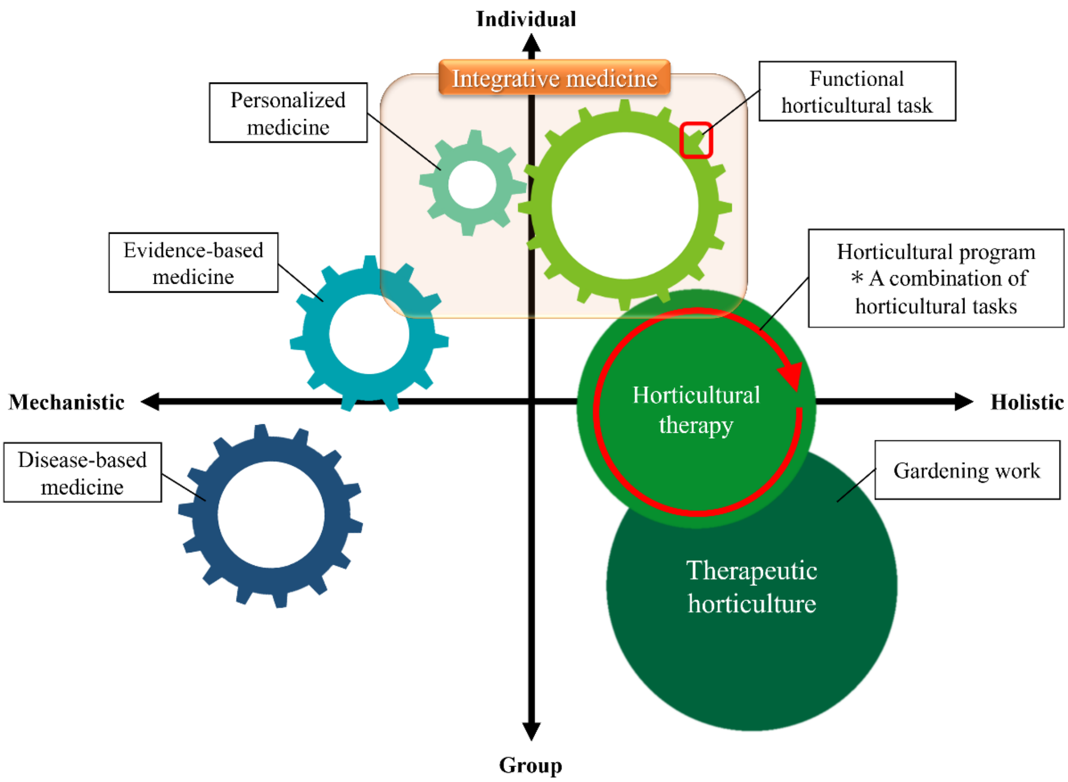

Figure 2. Systems approach to horticultural therapy for integrative medicine

1. 7. Purpose and scope of this research

The purpose of this study was to redefine the essence of HT so that it could be uniquely understood, and to establish a framework for integrating HT with WM. To achieve this, I conducted research according to the following four goals. (1) To clarify the mechanism of action that produces a therapeutic effect by applying systems thinking to HT. (2) To develop a functional horticultural task that has a positive effect on the patient's mental and physical functions based on the HT system model. (3) To apply systems dynamics to HT to build a system dynamics model that will be a tool to support rational decision-making by horticultural therapists. (4) To apply the PDCA cycle to HT and build a framework for improving the treatment plan of HT in a long-term and systematic manner according to the physical and mental condition of the patient.

1. 8. Academic significance of this research

So far, treatment with HT has been planned based on the experience of horticultural therapists. Therefore, the treatment method differed depending on the experience and knowledge of the horticultural therapist, and the reproducibility of the effect was low. Indicators for horticultural therapists to rationally design functional horticultural tasks and dynamic frameworks for improving treatment plans over the long term can lead to unification of treatment methods and increased reproducibility of effects. I believe that it will increase the professional value of horticultural therapists and promote treatment in combination with WM.

The HT system model can visually understand the significance of treatment and its method from a holistic perspective on the patient. I believe that it can help inexperienced horticultural therapists learn about the essences and methods of HT and promote understanding. The HT system model can also serve as a tool for sharing information about HT treatment with medical and welfare professionals and may help facilitate IM research.

Chapter 2 | Horticultural therapy affordances that elicit the active behavior of patients

2. 1. Introduction

Historically, the therapeutic effect of HT has been thought to occur through the dynamic interaction of the tasks presented to the patient by the therapist within the working environment. Previous studies have proposed several models to understand the process by which the effects of HT occur [4, 43]. These help to understand the position of the patient and the therapist, but the specific process by which the therapeutic effect is produced has not been clarified.

It has been clarified that high SE for treatment has an influence on the improvement of the patient's mental health. SE is a concept advocated by social psychologist Albert Bandura, and is considered to be a recognition that one can overcome the events that they face [44]. Patients with NCDs have been reported to promote health-related behaviors by having a high SE for treatment [45-48]. It has been shown that high SE-based action (active behavior) improves anxiety and depression in patients with dementia and NCDs [49]. It is also important to elicit active behavior in order to support the recovery of patient functions in HT.

Practical environment affordances designed by horticultural therapists can be used to elicit active behavior of patients in HT. Affordance is a concept advocated by ecological psychologist JJ Gibson, which is defined as the possibility of actions presented to humans by the environment. [50]. In the field of biological psychology, it has been suggested that the following three factors are involved in affordance [51]: (1) Physical characteristics such as color and shape, texture, and directionality of the object; (2) Distance between the object and the perceiver (near or far); and (3) Whether the physical properties of the object match the perceiver's preferences.

Even if it is known that SE and affordance in the environment are involved in the recovery of human function, it is not possible to understand the treatment method unless the process of interaction of these elements is clarified. Systems thinking is a methodology for solving complex events. It is a method of considering a complex process consisting of multiple elements and causal relationships as one system. Systems thinking has been applied as a methodology for understanding complex events in fields such as economics, nursing, and public health [52-54].

The purpose of this study was to apply systems thinking to HT and clarify the causal relationship between the patient and the components in the practical environment. Furthermore, based on the system model constructed, the essential objectives, subjects, and methods of treatment of HT were examined.

2. 2. Applying systems thinking to horticultural therapy

When HT is regarded as a system, the patient and the horticultural therapist can be positioned as a subsystem. Here, I extracted the components in the "patient" and "therapist" subsystems.

2. 2. 1. Extraction of HT system components

(a) Components in the patient subsystem

An important component of the patient is self-efficacy (SE). SE is a mental indicator in medicine, a cognitive self-evaluation that determines how well one can cope with the events one faces [44]. Previous studies have reported that patients with high SE recover faster than those with low SE [48]. It has been revealed that SE is processed in the prefrontal cortex [55]. It is generally known that cognitive function operates by inputting information on the external environment via the sensory organs. The sensory organs include sight, smell, hearing, touch, and taste. Humans perceive information and stimuli in the external environment through these sensory organs. Then, after the information is transmitted to the brain region as an electrical signal, the information is processed by the cognitive function localized in the brain, and it is considered that the height of SE is determined in the process and output as an action.

Human cognition and action are closely related to the nerve cells and neural circuits that make up the brain. For a long time, it has been thought that nerve cells and neural circuits that have disappeared or declined will never return. However, in current brain science, it is known that nerve cells and neural circuits in the human brain repeat development and build. This property is called brain plasticity. For example, it has been suggested that even if a certain neural circuit disappears due to a stroke, it is possible to acquire a neural circuit that complements, replaces, or replaces the function by receiving treatment, and the physical function can be reacquired [56].

In previous studies, the inactivation of cognition and action is thought to cause the decline of nerve cells and neural circuits on which their functions depend, and a negative spiral in which other functions also decline [57, 58]. However, it is said that even in aging, by re-engaging nerve cells and neural circuits in cognitive and action, it is possible to induce brain plasticity to produce positive effects [58].

From this scientific knowledge, it was concluded that it is important for HT to use the practical environment to circulate the patient's perception→ cognition→ SE→ action (active behavior) in order to support functional recovery. Therefore, the components of the "patient" subsystem are defined as perception, cognition, SE, and action.

(b) Components of the therapist subsystem

It is important for the therapist to elicit the active behavior of the patient. Ecological psychology proposes affordance as an element that induces human perception and action. [50] An affordance is the possibility of an act provided to humans by the environment. For example, mulberry affords us to "dig up the soil." Those who perceive an affordance recognize whether it causes an action to "plow the field." At that time, if the perceiver is induced to have a high SE, it is output as an action. On the other hand, if the perceiver does not induce or perceive a high SE, it is not output as an action. Affordances in the external environment are closely related to human perception and determine whether to elicit human SE and action.

Biological psychology has reported that affordances that elicit human visual attention are caused by the interaction of three elements (Fig. 3) [51]: (1) Physical characteristics such as color and shape, texture, and directionality of the object; (2) Distance between the object and the perceiver (near or far); and (3) Whether the physical properties of the object match the perceiver's preferences.

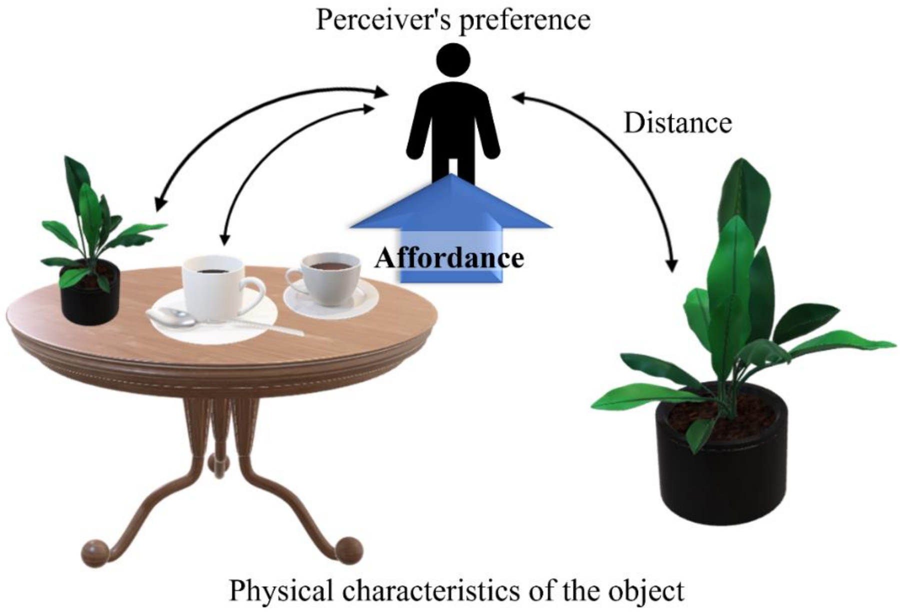

Figure 3. Affordance and the elements that create it. An affordance (blue arrow) is caused by the physical characteristics of the object, the distance between the object and the perceiver, and the perceiver's preferences.

Based on the scientific knowledge of biological psychology, I extracted the components in the practical environment. Objects in the working environment include plants and tools used in horticultural work, and horticultural therapists. In addition to color, shape, size, and directionality, the physical characteristics of plants include weight, aroma components, and functional components. The tools for cultivating it are color, shape, size, directionality, and weight. When a horticultural therapist is regarded as an object, the individual's facial expression, voice, clothes, and standing figure can be regarded as physical characteristics. In the practical environment of HT, it is considered that components such as plants and tools in horticultural work and horticultural therapists interact to generate affordances (Fig. 4). For example, if seeds, planters, and soil are prepared in the practical environment, the perceptual patient may receive an affordance such as "sowing."

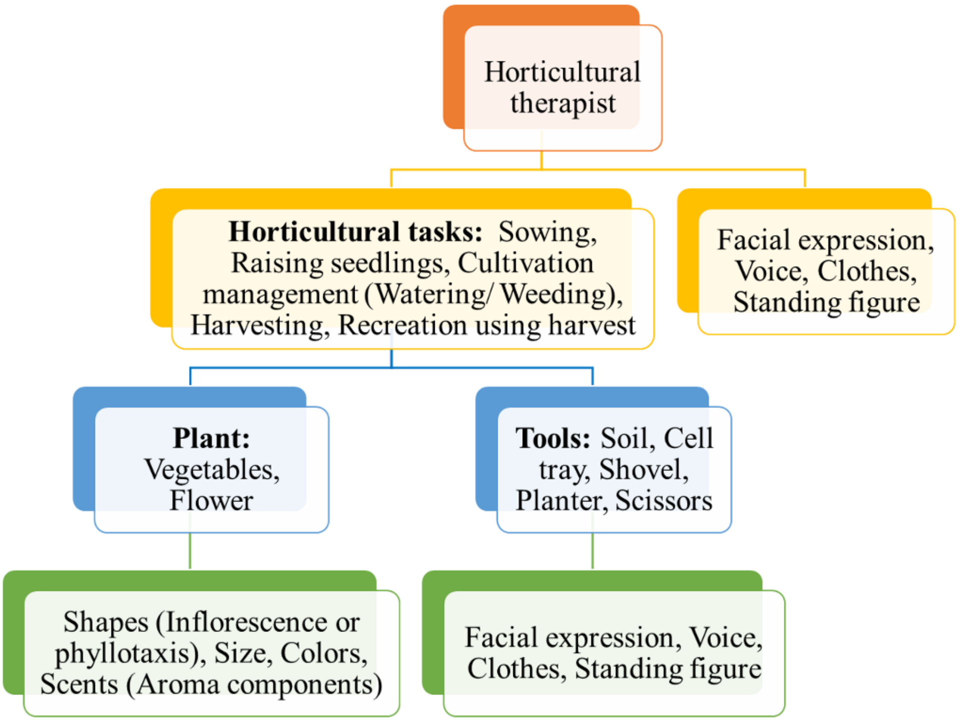

Figure 4. Components included in the therapist subsystem in horticultural therapy

2. 2. 2. Causal relationships between components of the horticultural therapy subsystems

In ecological psychology, humans are thought to repeat perception and behavior through affordances. Based on this theory, it can be considered that the practical environment of HT and the patient interact cyclically (Fig. 5). Figure 5 shows the HT process model. Through that model, I thought that horticultural tasks designed by horticultural therapists could influence patient perception→ cognition→ SE→ action through affordances. Since patient actions are based on high SE, it is important for horticultural therapists to design horticultural tasks and practical environments that bring out the patient's high SE. As a method of designing horticultural tasks, physical properties such as color and size of plants and tools can be used.

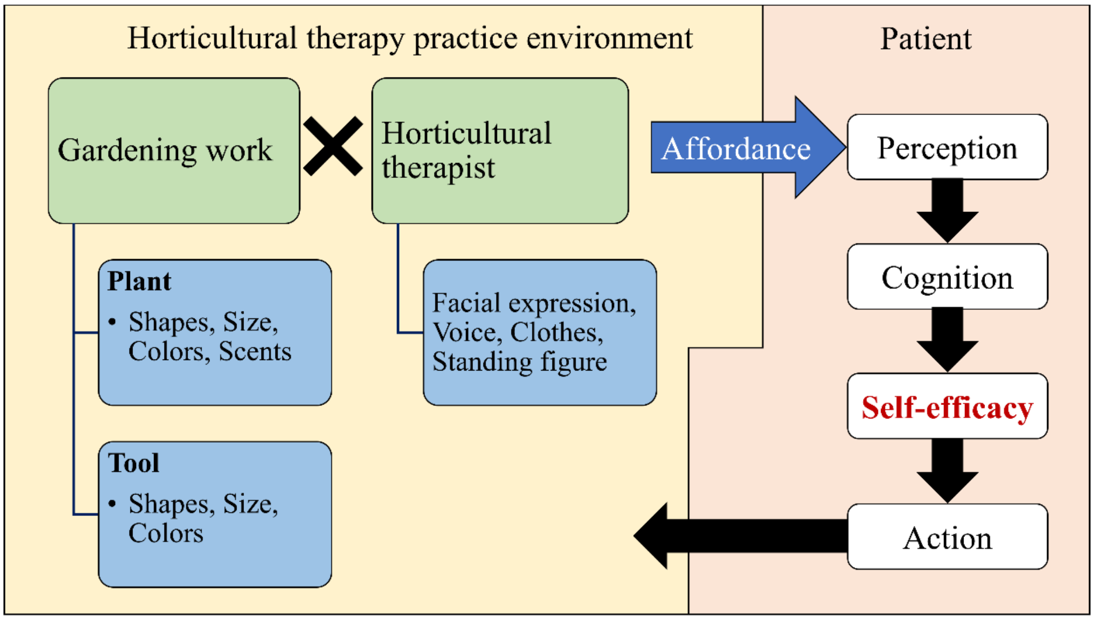

Figure 5. HT system model based on affordance theory. In the HT system, a horticultural task designed by a horticultural therapist circulates the patient's perception→ cognition→ self-efficacy→ action through affordances.

2. 3. Importance of affordances that elicit patient perception and action

J. J. Gibson argues that if humans do not perceive affordances, processes such as cognition and action do not occur. For example, suppose you have a chair with a height of 50 cm. Tall adults receive affordances such as "sitting" from the chair. On the other hand, a one-year-old child will receive affordances such as "grabbing" and "walls" from the chair. If both adults and children are blind, they may receive affordances such as "things that make sounds" and "things that touch."

Even if the patient can perceive the horticultural task, no action will occur unless it can be put into action. For example, tools for watering plants include watering cans with a capacity of 10, 5, 3, and 1 L and PET bottles with a capacity of 500 ml. If a patient with weak muscles is provided with 10 L watering can, the patient sees the watering can and decides that it is "difficult to lift." By providing a 500ml PET bottle instead of the watering can, the patient will decide that he can "lift" and work on the horticultural task. It is important for horticultural therapists to set up affordances that patients can perceive for horticultural tasks and to prepare plants and tools that can put them into action.

2. 4. How to make affordances that elicit the active behavior of patients in horticultural tasks

In order for humans to perceive tasks and take action, it is necessary to induce high SE. Self-efficacy theory states that accumulating successful experiences is the most powerful source of information that enhances SE [3]. A "successful experience" is an experience obtained by performing or acting on a task in the past. Just as I provided a 500 ml PET bottle to a weakened patient, it is important for the horticultural therapist to design the horticultural task so that the patient can accumulate successful experiences of horticultural tasks [59].

The height of SE in humans is also said to vary depending on physiological and emotional states. Physiological and emotional states are beliefs about anxiety, fatigue, and pain caused by performing tasks. For example, flowers and vegetables that cause toxicity and allergic symptoms provide an affordance of "negative effects" on any patient. On the other hand, flowers with the patient's favorite scent and color provide an affordance that "has a positive effect." The fact that the scent of plants depends on the physiological and emotional states of the patient is supported to some extent by scientific evidence [60, 61]. It is important for horticultural therapists to create affordances that can be perceived as having a “positive effect.”

2. 5. Conclusions

By applying systems thinking to HT, the HT system was considered to consist of a "patient" and a "therapist" subsystem. Based on the findings of social psychology and cognitive neuroscience, the components of the "patient" subsystem were defined as perception, cognition, self-efficacy, and action. Based on the scientific findings of ecological and biological psychology, the components of the "therapist" subsystem were defined as horticultural tasks. The causal relationship of the components of each subsystem is perceived and acted on by the patient through the affordance of the practical environment designed by the therapist based on the affordance theory. Through the system model of HT, I conclude that the goal of treatment is to increase the patient’s SE. The purpose is to circulate the patient's perception→ cognition→ high SE→ action (active behavior). In order to elicit that active behavior, it is important to design affordances that elicit perception and horticultural tasks that enhance SE. The therapist can be said to be an expert in developing horticultural tasks that use plants and tools to elicit the active behavior of patients. In the future, it will be important to scientifically verify the effectiveness of the devised horticultural tasks and increase the number of functional horticultural tasks that have proven useful.

Chapter 3 | Development of a horticultural task based on the horticultural therapy system model and verification of the effect

3. 1. EXPERIMENT 1: The effect of reproducing two-dimensional photographs of flower arrangements in three dimensions on prefrontal blood flow in elderly patients with dementia

3. 1. 1. Introduction

Increasing local cerebral blood flow (rCBF) is important for suppressing the progression of dementia. It is known that the progression of dementia is associated with a chronic decrease in rCBF [62]. Various pharmacological and non-pharmacological therapies have been studied to ameliorate the deterioration of the psychological, cognitive, and physical conditions caused by dementia [63-68]. However, a treatment for dementia has not yet been established.

rCBF increases when cognitive activity is activated and decreases when it is deactivated. In dementia, blood flow in the prefrontal cortex is chronically reduced [69, 70]. The prefrontal cortex is responsible for higher cognitive activities such as emotions, working memory, planning, and decision making. Therefore, it may be possible to increase rCBF by activating those cognitive functions.

Flower arranging (FA) is a horticultural task that uses multiple cut flowers to create vertical, horizontal, and triangular layouts. While the patient is carrying out this task, cognitive function in the prefrontal cortex may be activated, meaning that FA may increase blood flow in the prefrontal cortex. In HT, FA is used as an indoor horticultural task [71]. The main purpose of FA is expected to be relaxation and improvement of mood [72]. However, it has been observed that there are individual differences in the effects of a horticultural task such as FA. In addition, the therapeutic target and working hypothesis of FA are unclear. In the treatment of dementia, it is important to clarify the effect of FA and improve its reproducibility.

In HT for elderly patients with dementia, the therapeutic goal is to increase rCBF. General FA depends on individual creativity, which is associated with personality traits such as openness, extraversion, and integrity [73]. Therefore, there is a high possibility that there are individual differences in terms of the effect that general FA has on prefrontal blood flow. I removed the creativity of FA and created a 2D task aimed at activating two cognitive functions of the prefrontal cortex: visuospatial cognition and working memory.

In this section, I have formulated two hypotheses about the effects of FA and 2D tasks. First, there are individual differences in rCBF during FA, but not during the 2D task. Second, the 2D task activates rCBF in older patients more than FA. The reason is that the 2D task specified a cut flower layout to support the patient's visuospatial cognition and working memory activity. To prove these hypotheses, this experiment evaluated and compared prefrontal cortex blood flow during FA and 2D tasks in elderly women.

3. 1. 2. Materials and Methods

3. 1. 2. 1. Participants

Twelve elderly women at Japanese nursing care facilities who met the following conditions were selected by the facility's full-time doctors and caregivers: (1) aged 65 and over and cognitively healthy or with mild to moderate dementia, (2) ability to perform tasks, and (3) right-handedness. The suitability of condition 1 was judged from the revised Hasegawa simple cognitive evaluation scale, and the suitability of condition 2 was judged from the degree of long-term care required and activities of daily living. Condition 3 was judged by declaration from participants. All participants were briefed on the content of the experiment and agreed in writing to informed consent. This experiment was conducted in compliance with the Declaration of Helsinki.

3. 1. 2. 2. FA materials

The following materials were prepared for use in FA. Cut flowers: 5 roses (red), 10 gerberas (5 each in yellow and orange), 5 sweet peas (white), and 2 leather fans (green). The tools provided were gardening shears for cutting cut flower stems and leaves, rubbish bins, vases, and floral foam (Smithers-Oasis Company, Ohio, USA). A softer type (springtime) of floral foam was used rather than the basic rigid (standard) type. Because muscle strength decreases with aging, the floral foam was cut into squares in advance according to the shape of the vase (11 cm length x 11 cm width x 10 cm height). It was soaked in water and set in a vase. The materials were prepared in a fixed position on the desk so that they would be placed in the same layout for all participants. All of the materials were place within the reach of the participants while they were sitting and within a radius of approximately 30 cm.

3. 1. 2. 3. FA contents

All participants were instructed to do FA using the plants and tools prepared on the desk. Participants freely performed the task using cut flowers and tools as instructed. The time to perform this task was not limited by the experimenter, but most participants completed it in approximately 15 minutes.

3. 1. 2. 4. 2D task contents

The 2D task is a horticultural task aimed at activating visuospatial cognition and working memory to increase prefrontal cortex blood flow. The experimenter created the layout using the same materials used in this experiment (Fig. 6). The layout was determined for each type of cut flower and was photographed from directly above and from the side. As a result, the information (shape, color, and placement position) required for the patient to lay out the flowers became two-dimensional. These two photographs were printed together on A3 paper and laminated. Participants were required to memorize the 2D information and create a three-dimensional layout. In the process, it was thought that visuospatial cognition and working memory were activated. I call the actual execution of the horticultural task based on the 2D information a 2D task. The time to perform the 2D task was not limited, but most participants completed it in approximately 15 minutes.

Figure 6. Layout of 2D task adopted in this experiment.

3. 1. 2. 5. Measurement of dlPFC blood flow

Prefrontal cortex blood flow during each task was measured using HOT-1000 (NeU Co., Ltd., Tokyo, Japan). In the center of the device, two channels of near-infrared light (wavelength 600 to 800 nm) are installed at 3 cm intervals. Near-infrared light is emitted from the light source toward the left and right dlPFC, and the reflected light that is not absorbed by the hemoglobin in the blood is detected by the light-receiving sensor. This makes it possible to measure relative changes in blood flow over time. The noise of the dlPFC blood flow data generated by the movements of the participants was removed by the HOT-1000 dedicated software. The acquired dlPFC blood flow data was converted into waveform data. The reference value of the waveform data was set at rest, but several participants spoke during the resting period. Therefore, the minimum value of dlPFC blood flow measured during each task was used as a reference and subtracted from the total numerical data. The integrated value of the data was treated as the total blood flow during each task.

3. 1. 2. 6. Experimental procedure

To reduce the psychological or physical burden on the participants, an experimental space was set up in the nursing care facility that the participants use daily. The experiment space was partitioned so that participants would not meet other participants during the experiment, and tables and chairs were prepared to practice the tasks. The space was maintained at a temperature and humidity that participants felt comfortable with.

Participants were invited by a caregiver to the experimental space and sat in chairs or wheelchairs. Then, the experimenter introduced himself and explained the safety of HOT-1000. After that, the experimenter put the device on the participant's head and confirmed the experiment procedure and precautions. The experimenter confirmed with the participants that they were in good health, asked if they had any requests, instructed them to talk as little as possible during the experiment, and asked them to stop the experiment if they felt at risk physically or mentally. After all confirmations were completed, all participants performed resting state, FA, resting state, and FA with the 2D task (Fig. 7). The measurement of dlPFC blood flow started at the first rest and was continuously measured until the FA with the 2D task was completed.

Participant	1. Self-introduction 2. Installation of HOT-1000 3. Explanation of experimental procedure	4. Rest	5. FA	6. Rest	7. 2D task
Experimenter	HOT-1000 measurement	Start →			
Time required	5 - 10 min	Approx. 2 min	Approx. 15 min	Approx. 2 min	Approx. 15 min

Figure 7. Experiment participants and the execution contents and procedures of the experimenters. FA means general flower arranging. 2D task means FA aimed at activating the visuospatial cognition and working memory of elderly patients.

3. 1. 2. 7. Statistical analysis

The total dlPFC blood flow in each task was divided by the working time (minutes) to calculate the dlPFC blood flow per unit time. The Shapiro-Wilk test was performed to examine the normality of dlPFC total blood flow and dlPFC blood flow per unit time in each task. Wilcoxon signed rank sum test was performed between each task for the total blood flow of dlPFC and the blood flow per unit time. All statistical analyses were conducted using IBM SPSS Statistics version 25 (IBM, Armon, NY, USA).

3. 1. 3. Results and Discussion

3. 1. 3. 1. Basic attributes of participants

Nine participants completed the experiment. The reasons for discontinuation for the other participants were malfunctioning Bluetooth connection between the measuring device and the data acquisition device (n = 1), participant fatigue (n = 1), and incorrect execuction of the experimental procedure (n = 1). For the data analysis, I used the cerebral blood flow data of the 9 participants who completed the experiment. The basic attributes of the participants are shown in Table 2. The higher the value of the nursing care index, the lower the physical and mental condition. A lower dementia index indicates more advanced dementia.

Table 2. Basic attributes of participants.

	Average	Range	SD
Age	86.9	82-91	2.67
Nursing care index	2.3	1 - 4	1.00
Dementia index	18.7	10 - 30	6.08

3. 1. 3. 2. dlPFC blood flow change pattern

In this experiment, changes in dlPFC blood flow during each task were continuously measured. The reference value at the time of measurement was dlPFC blood flow at rest, but some participants spoke at the time of measurement. Therefore, it was difficult to measure an accurate reference value.

There are nine patterns of dlPFC blood flow changes predicted for each task. In this experiment, three of them were observed (Table 3). Figure 7 displays the waveform data of these three patterns (Fig. 8). In the figure, the change in dlPFC blood flow on the left side is represented by the blue line, and the change on the right side is represented by the red line. Since the personal information of all participants was anonymized, the waveform data was indicated by the participant's identification code (A, B, and C). The start and end times of each task are indicated by dotted lines.

Table 3. Prediction type and measurement result of dlPFC blood flow change pattern in each task.

FA	2D task	n
L≒R	L>R	0
	L<R	0
	L≒R	2
L>R	L>R	5
	L<R	0
	L≒R	2
L<R	L>R	0
	L<R	0
	L≒R	0

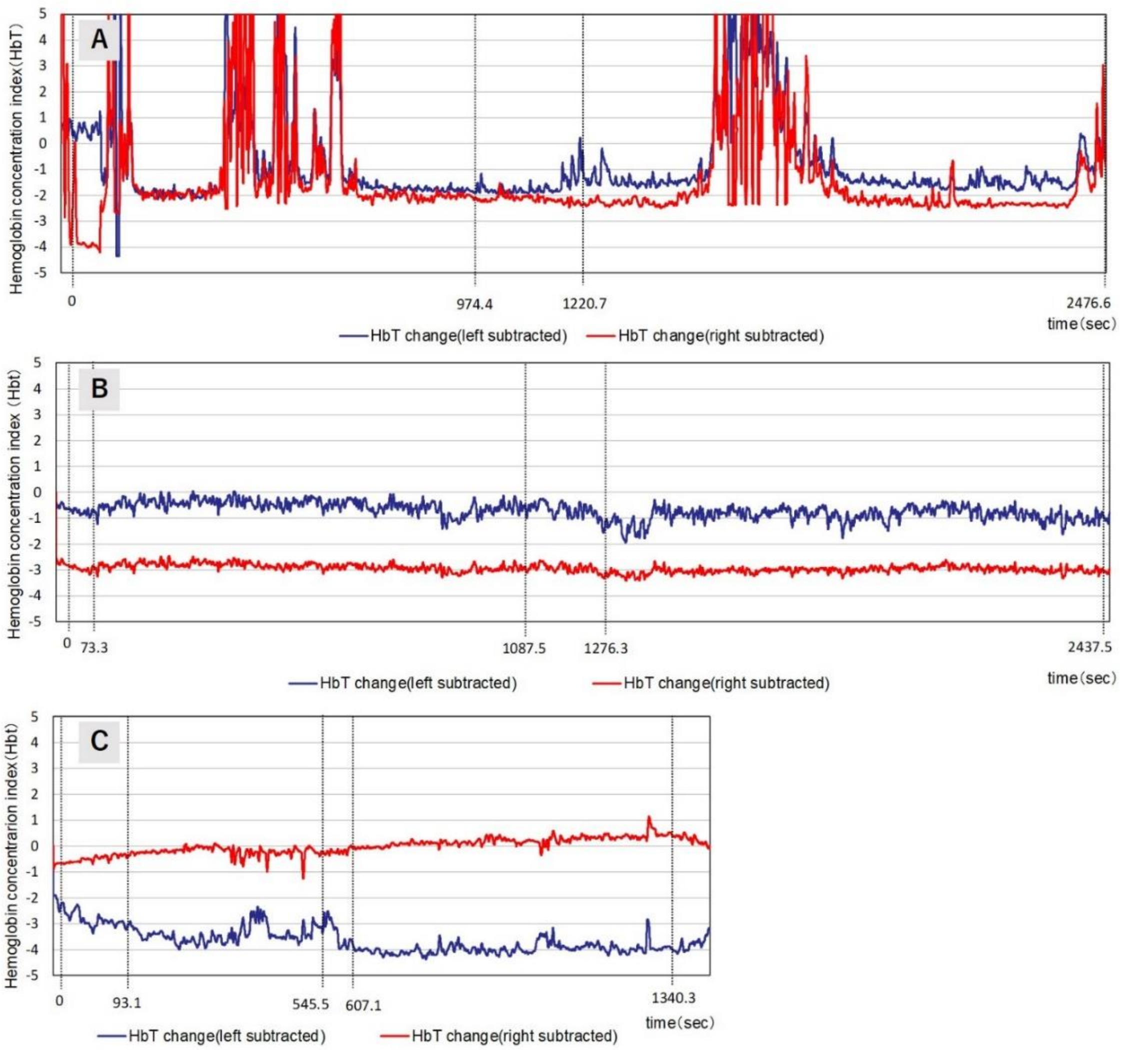

Figure 8. Changes in dlPFC blood flow during each task in participants (A, B, and C). The vertical axis is the relative hemoglobin concentration, which is an index of blood flow change, and the horizontal axis is time (sec). The blue line is the left, and the red line is the right dlPFC blood flow change. The dotted line in the table A shows the time of FA start, FA end, 2D task start, and 2D task end from the left. The dotted lines in Tables B and C show the times of rest start, FA start, FA end, 2D task start, and 2D task end from the left.

Participant A shows similar changes in dlPFC blood flow between the FA and 2D tasks. In Participant B, the dlPFC blood flow on the left side was predominant over the right side, and in Participant C, the dlPFC blood flow on the right side was predominant over the left side. As a result of comparing the patterns of three dlPFC blood flow changes, the blood flow changes in the left and right dlPFC regions differed depending on the participants even if the task contents were the same. Patients with Alzheimer's disease (AD) have been reported to have different perfusions in the left and right regions compared to those with mild cognitive impairment (MCI) [74]. In this experiment, I targeted a wide range of elderly patients who were cognitively healthy or had mild to moderate dementia, so the various waveform patterns observed were expected. Various studies have been conducted on the difference in function between the left and right dlPFC, but this difference is not clear. Some previous studies suggest that the dlPFC activity on the left may be responsible for reasoning or working memory, and on the right may be responsible for visuospatial cognition or emotion. In this experiment, the dlPFC blood flow change pattern in each task was predominantly left dlPFC blood flow in half of the participants. FA has shown the potential to activate reasoning, working memory, and visuospatial cognition, but further research is needed.

The results of this experiment showed similar changes in dlPFC blood flow on the left and right sides while practicing FA and 2D tasks, but individual differences were observed in both cases (Fig. 8). These results revealed that individual differences in therapeutic effects also occur in 2D tasks that exclude creativity in FA. However, when the three dlPFC blood flow change patterns were compared in detail while practicing each task, the timing at which the peak value appeared, indicating an increase in dlPFC blood flow, was different. These results suggest that the FA and 2D task have the same work classification, but the therapeutic effect differs depending on the content. In HT, gardening is horticulturally categorized, for example by sowing, raising seedlings, irrigation, weeding, and harvesting. In the future, it will be important to use physiological indicators such as dlPFC to identify what kind of plants and tools the participants used and when the peak value was displayed. It may be possible to clarify the elements of the therapeutic effect within the horticultural task. Furthermore, by classifying according to these factors and the characteristics of the treatment target, disease, plants, and tools, an HT-specific classification list can be created for a horticultural task according to the patient's type of disease and therapeutic effect. The list should preferably include elements validated using physiological indicators such as dlPFC, treatment goals and targets, selected horticultural tasks, and plants and tools used. The list may help therapists design specialized programs that can complement the treatment of dementia.

3. 1. 3. 3. Significant difference test of dlPFC blood flow during each task

As a result of examining the significant difference between the total dlPFC blood flow rate and the dlPFC blood flow rate per unit time between each task, no statistically significant difference was observed ($p > .05$). The difference was calculated by subtracting the dlPFC blood flow per unit time during FA from the dlPFC blood flow per unit time during the 2D task. There were 6 participants whose left dlPFC blood flow was increased by the 2D task more than FA, and

7 participants whose right dlPFC blood flow was increased by the 2D task (Table 4). In AD, increased blood flow in the left dlPFC has been reported to improve cognitive function [75-77]. The results of this experiment suggest that adding a 2D task to FA can increase dlPFC blood flow. In the future, it will be important to use physiological indicators such as dlPFC to develop effective horticultural tasks for therapeutic targets in patients with dementia.

Table 4. Differences in dlPFC blood flow per unit time between tasks. The alphabet is the participant's identification code. Left and right represent the dlPFC region. (+) and (-) indicate increase and decrease in dlPFC blood flow, respectively.

Participant	dlPFC	
	Left	Right
A	-	-
B	+	+
C	+	+
D	+	+
E	+	+
F	+	+
G	+	+
H	-	+
I	-	-

HT is a non-pharmacological therapy, with mainly psychological effects such as improving the patient's self-efficacy and mood. Dementia often develops in old age, and other diseases may also be present at that time. The cooperation of western medical experts is required to enhance the effectiveness of HT. HT has been practiced based on the knowledge and skills gained from the experience of horticultural therapists. One of the techniques is to design horticultural tasks according to the patient's age and illness, mental and physical functions, and preferences. To support the understanding of other professionals, especially those of WM, it is important to clarify the usefulness of the technique through physiological indicators. I believe that such an understanding will promote the spread of HT in the medical and welfare environment.

3. 1. 4. Conclusions

FA and 2D tasks were performed to increase rCBF blood flow in cognitively healthy or elderly people with mild dementia. A 2D task is a task aimed at increasing blood flow in rCBF by removing the creativity associated with FA. rCBF blood flow during each task was measured over time using HOT-1000. From the measured waveform data, there were three patterns of rCBF blood flow changes during each task. No statistically significant differences were observed among the differences in dlPFC blood flow per unit time for each task. However, 6 patients increased left dlPFC blood flow with a 2D task, and 7 patients increased right dlPFC blood flow. This suggests that the FA and 2D tasks are the same types of tasks, but the therapeutic effects are different due to differences in content. In the future, it will be important to determine the elements of the horticultural task that can improve the therapeutic target using physiological indicators such as dlPFC blood flow. Horticultural tasks created based on these factors may help control the progression of dementia.

3. 2. Experiment 2: Functional horticultural tasks activating higher cognitive function increase prefrontal cortex blood flow in patients with Alzheimer's disease

3. 2. 1. Introduction

Patients with Alzheimer's disease (AD) have decreased prefrontal cortex (PFC) blood flow. The main clinical symptoms of AD are deterioration of cognitive function and activities of daily living [78]. Its pathological features include amyloid β [79] accumulation and brain atrophy [80] in brain region. In recent years, cerebral ischemia has been shown to exacerbate these symptoms [81-83]. Mild cognitive impairment (MCI) and mild AD cause a chronic reduction in PFC perfusion [77, 84, 85]. Decreased cerebral perfusion is also a known risk factor for developing AD [86]. To prevent the onset and progression of AD, it is necessary to prevent a chronic decrease in cerebral perfusion.

PFC blood flow can be increased by activating higher cognitive function. The PFC controls higher cognitive functions such as working memory, planning, problem solving, and decision making [87]. Previous studies have shown that activating cognitive function in a brain region increases blood flow to that region [88, 89].

Flower arranging (FA) includes several elemental tasks and processes that activate higher cognitive functions. FA is a horticultural task that uses multiple cut flowers to create a three-dimensional (3D) layout. It consists of five elemental tasks: (1) 3D layout determination, (2) cut flower variety selection, (3) cut flower leaf and stem shaping, (4) cut flower placement position, and (5) confirmation of the overall layout. These elemental tasks activate selection and decision-making, judgment, and visuospatial cognition [90]. Furthermore, it is necessary to plan and execute the order of executing these elemental tasks. Previous studies have reported that FA increases PFC blood flow in healthy adolescents [72].

When providing FA to patients with AD, it may be necessary to add functionality that activates working memory. Patients with AD have decreased cognitive function centred on working memory starting from the initial stage of the disease. I designed a 3D layout to activate higher cognitive function in patients with AD. Next, I created a functional horticultural task that activates working memory by providing the layout information to the patient in a two-dimensional (2D) photograph and asking the patient to reproduce it in a 3D layout. A horticultural task with the functions necessary to treat a specific disease is defined as a functional horticultural task. The functional horticultural task I created for this study was named the 2D-3D task. To complete the 2D-3D task, it is necessary to memorize the colours and shapes of the cut flowers in the photograph and select the type of cut flowers to reproduce the image in the photograph. Similarly, for other elemental tasks, it is necessary to memorize the necessary actions during the process of reproducing the 3D layout based on the 2D information. Therefore, I hypothesized that the 2D-

3D task activates higher cognitive functions, including working memory, in patients with AD and increases PFC perfusion.

In this section, dorsolateral prefrontal cortex (dlPFC) blood flow in patients with AD was measured while performing the 2D-3D task. I investigated whether the task could increase dlPFC blood flow. It has been suggested that cognitive function in patients with AD might decline as dementia progresses. Therefore, I investigated the relationship between task-derived dlPFC blood flow increase and degree of dementia progression [83]. The revised Hasegawa's Dementia Scale-Revised (HDS-R) score was evaluated before the experiment as a measure of the degree of dementia progression.

3. 2. 2. Methods

3. 2. 2. 1. Participants

Study participants were recruited at a Japanese long-term care facility. Inclusion criteria included (1) AD diagnosed by the doctor in charge, (2) determination that the participant's physical and mental condition and pre-existing illnesses will likely not worsen by performing the functional horticultural task, and (3) right-handedness. These conditions were evaluated by the doctor and caregiver in charge of the care facility. This study was carried out in compliance with the Declaration of Helsinki. The safety of this experimental protocol was recognized by the ethics committee of the Faculty of Agriculture of Kindai University (reception number: 2009-2). This experiment was registered in the clinical trial system of the University Hospital Medical Information Network (UMIN) Research Center (UMIN trial ID number: UMIN000037568).

3. 2. 2. 2. Evaluation of dementia progression

The degree of dementia progression was evaluated using HDS-R before the experiment. This evaluation scale is typically used in Japan because of its high accuracy and quick implementation [91]. The HDS-R consists of nine questions for investigating higher cognitive dysfunction: (1) age, (2) orientation to time, (3) orientation to space, (4) immediate recall, (5) calculation, (6) digits in reverse, (7) delayed recall, (8) item memory, and (9) speech fluency. The maximum score is 30 points. Dementia is defined as 20 points or less. The scale is known to be a reference for the progression of dementia. The cutoff values are 24 ± 4 (no dementia), 19 ± 5 (mild dementia), 15 ± 4 (moderate dementia), 11 ± 5 (slightly severe dementia), and 4 ± 3 (severe dementia). The degree of dementia progression was predicted from the total score. The types of higher cognitive dysfunction associated with the degree of dementia were predicted from the scores of each of the nine questions.

3. 2. 2. 3. Design of functional horticultural tasks

(a) Materials

The cut flowers consisted of 7 sunflowers, 17 pink spray carnations, 2 hypericums, and 2 narcolans. Gardening scissors, floral foams for arranging cut flowers (Smithers-Oasis Company, Ohio, USA), and flower bases were used to adjust the length of the stems (length 11 cm x width 11 cm x height 10 cm).

(b) Task content structure

The design of the 2D-3D task included two steps to activate higher cognitive function in patients with AD. The first step was to design a layout that activates the participants' visuospatial cognitive function while determining a 3D layout during FA. The layout was designed with reference to the clock drawing test (CDT). The CDT involves drawing a round circle on A4 paper and an analogue clock showing 11:10. Working memory related to visuospatial cognition can be evaluated based on the number and arrangement of drawn numbers and the accuracy of needle positions [92, 93]. In this experiment, the round circle in the CDT was likened to a circular floral form, and the numbers and hands of the clock were likened to cut flowers. Based on the 12 lines radiating from the centre of the floral form, the cut flowers were laid out so that the types and positions of the cut flowers had a 3D structure (Fig. 9).

The second step was to add a function to activate working memory during FA. The experimenter reproduced a 3D layout using cut flowers in advance. Photographs were taken from directly above, the front, and the back. The three photographs were displayed together on A4 paper (Fig. 10). Participants were instructed to reproduce the 3D layout from 2D information such as the type and placement of cut flowers shown in the photographs.

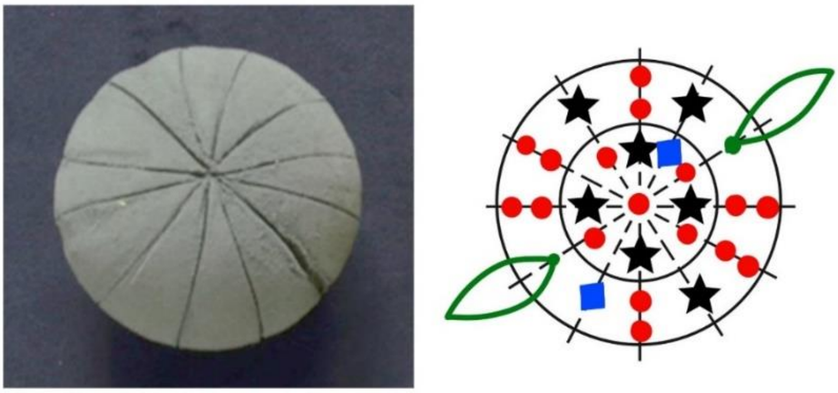

Figure 9. Task design to activate visuospatial cognition. Left: Floral form used in this experiment. Right: Flower arrangement layout. Symbols indicate the type, number, and position of cut flowers used: stars are sunflowers, circles are carnations, squares are hypericums, and leaves are narcolans.

Figure 10. Two-dimensional (2D) information on the three-dimensional (3D) layout used for the 2D-3D task.

3. 2. 2. 4. Functional near-infrared spectroscopy measurement

PFC blood flow was measured by near infrared spectroscopy. The measurement used a HOT-1000 device (NeU Co., Ltd., Tokyo, Japan). By attaching the device to the forehead of the participant, left and right (L/R) dlPFC blood flow can be measured. The front of the instrument is equipped with a light source that emits near-infrared light (wavelengths, 600 to 800 nm) that is easily absorbed by hemoglobin in the blood. Reflected light that is not absorbed by hemoglobin is detected by the sensor. The relative hemoglobin concentration [mM/mm] was measured as an index of L/R-dlPFC blood flow. The noise generated by the participant's body movements was automatically removed by a dedicated application program in the device.

Data was transferred via a connection between the device and an Android tablet. With this function, it was possible to reduce the invasiveness to the mind and body without restricting the movements of the participant. It was also optimal for evaluating the effects of the 2D-3D task associated with the participant's movements.

3. 2. 2. 5. Experimental protocol

This experiment was conducted in the multipurpose functional space of the facility where participants were recruited. The experiment space was partitioned so that other users could not see the participants. Desks and chairs were prepared.

A caregiver, a horticultural therapist, and a research staff member were involved in the experiment. First, the caregiver guided the participants to the experimental space. The horticultural therapist outlined the experiment to participants sitting in a chair or wheelchair and placed the HOT-1000 on their foreheads. Participants were instructed to rest for 2 minutes in that state. The therapist then prepared the materials to perform the 2D-3D task on the desk and instructed the participants to start the task. Participants memorized the type, length, and placement position of cut flowers from the 2D information on the layout and reproduced the 3D layout using actual materials.

The research staff member started the measurement when the participant had been in a resting state for 1 minute. Measurement continued until the participant completed the 2D-3D task. There was one participant who spoke in the middle of the rest period. The therapist spoke to the participants before starting the task. For these reasons, the lowest L/R-dlPFC blood flow at rest was treated as the baseline. L/R-dlPFC blood flow during the 2D-3D task was converted to waveform data. The integral of the waveform was calculated to examine total blood flow. The integral was divided by task time (minutes) to calculate L/R-dlPFC blood flow per minute, which was used for statistical analysis.

3. 2. 2. 6. Statistical analysis

The Shapiro-Wilk test was used to analyze total L/R-dlPFC blood flow during the 2D-3D task, blood flow per minute, total HDS-R score, and score for each HDS-R question. The Wilcoxon signed rank test was used to compare L-dlPFC and R-dlPFC total blood flow in each participant. The Pearson's product moment correlation coefficient was calculated between L-dlPFC and R-dlPFC blood flow per minute and the total HDS-R score. The Spearman's rank correlation coefficient was calculated for L-dlPFC versus R-dlPFC blood flow per minute and the score for each HDS-R question. IBM SPSS Statistics version 25 (IBM, Armonk, NY, USA) was used for statistical analysis. The significance level was $p < 0.05$.

3. 2. 3. Results

3. 2. 3. 1. Demographic characteristics of the study participants

Twelve patients with AD aged 65 years or older participated in this experiment. Four female participants were unable to complete the 2D-3D task. Since the total HDS-R score of these patients was 10 or less, the degree of dementia progression was slightly severe (11 ± 5) or severe (4 ± 3). These participants needed therapeutic verbal and physical support to complete the 2D-3D task. Therefore, dlPFC blood flow during the task could not be measured accurately. As a result, their data were excluded from the analysis.

Eight participants (one male and seven females) were able to complete the 2D-3D task independently (Table 5). Their average age was 88.6 years (range, 80–96; SD, 5.805). The average total HDS-R score was 14.8 (range, 10–19; SD, 3.615)

Table 5. Age and total Hasegawa's Dementia Scale-Revised (HDS-R) score of participants who completed the 2D-3D task. The table shows the average value, range, number of participants (n), and standard deviation (SD) in each item.

	Average	Range	n	SD
Age	88.6	80 – 96	8	5.81
Total HDS-R score	14.75	10 – 19	8	3.62
		17.85 ± 4.00	5	
		14.10 ± 4.46	3	

3. 2. 3. 2. dlPFC blood flow during the 2D-3D task

(a) Total blood flow

Total dlPFC blood flow during the 2D-3D task increased in the left and right regions in all participants (Fig. 11). There were individual differences in the amount of increase. The Wilcoxon signed rank test for L-dlPFC versus R-dlPFC total blood flow in the same participant did not show a statistically significant difference (p= 0.674). However, some participants (A–D, H) had increased total dlPFC blood flow predominantly on the left, while other participants (E–G) had increased flow predominantly on the right.

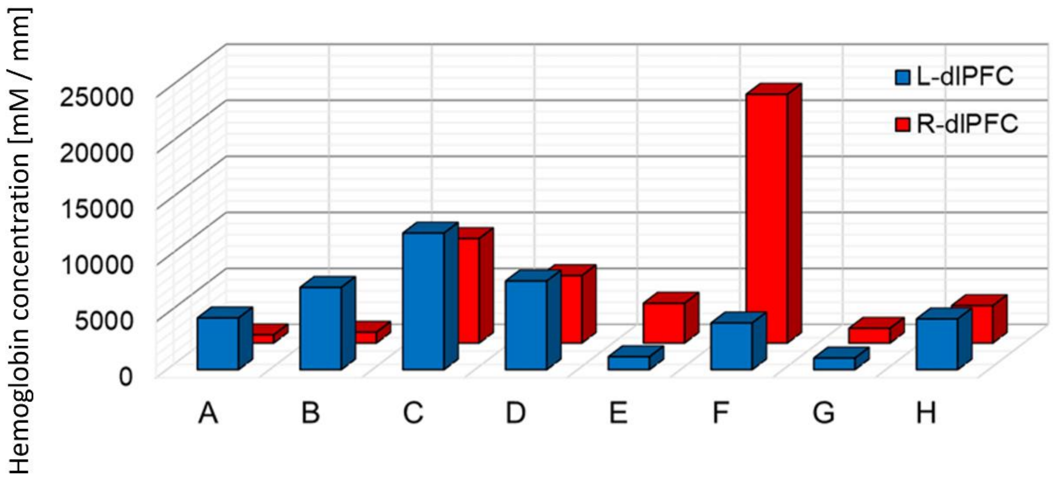

Figure 11. Total dorsolateral prefrontal cortex (dlPFC) blood flow during the 2D-3D task. The vertical axis is the hemoglobin concentration [mM / mm]. The baseline is the minimum dlPFC blood flow at rest. The blue bars show total dlPFC blood flow on the left (L-dlPFC). The red bars show total dlPFC blood flow on the right (R-dlPFC). The horizontal axis shows participant identification codes (A–H), which corresponds to the identification codes used in Fig. 10.

(b) Changes in blood flow over time

Since there was no limit to working time for the 2D-3D task, working time varied across participants (Fig. 12). The average working time was 517.5 seconds (range, 240–780; SD, 3.662). The blue line shows the change in L-dlPFC blood flow. The red line shows the change in R-dlPFC blood flow. The letters in this figure indicate the participant identification code, which corresponds to those in Fig. 11. The amplitude of waveforms indicated the amount of increase in dlPFC blood flow measured at 0.1 millisecond intervals.

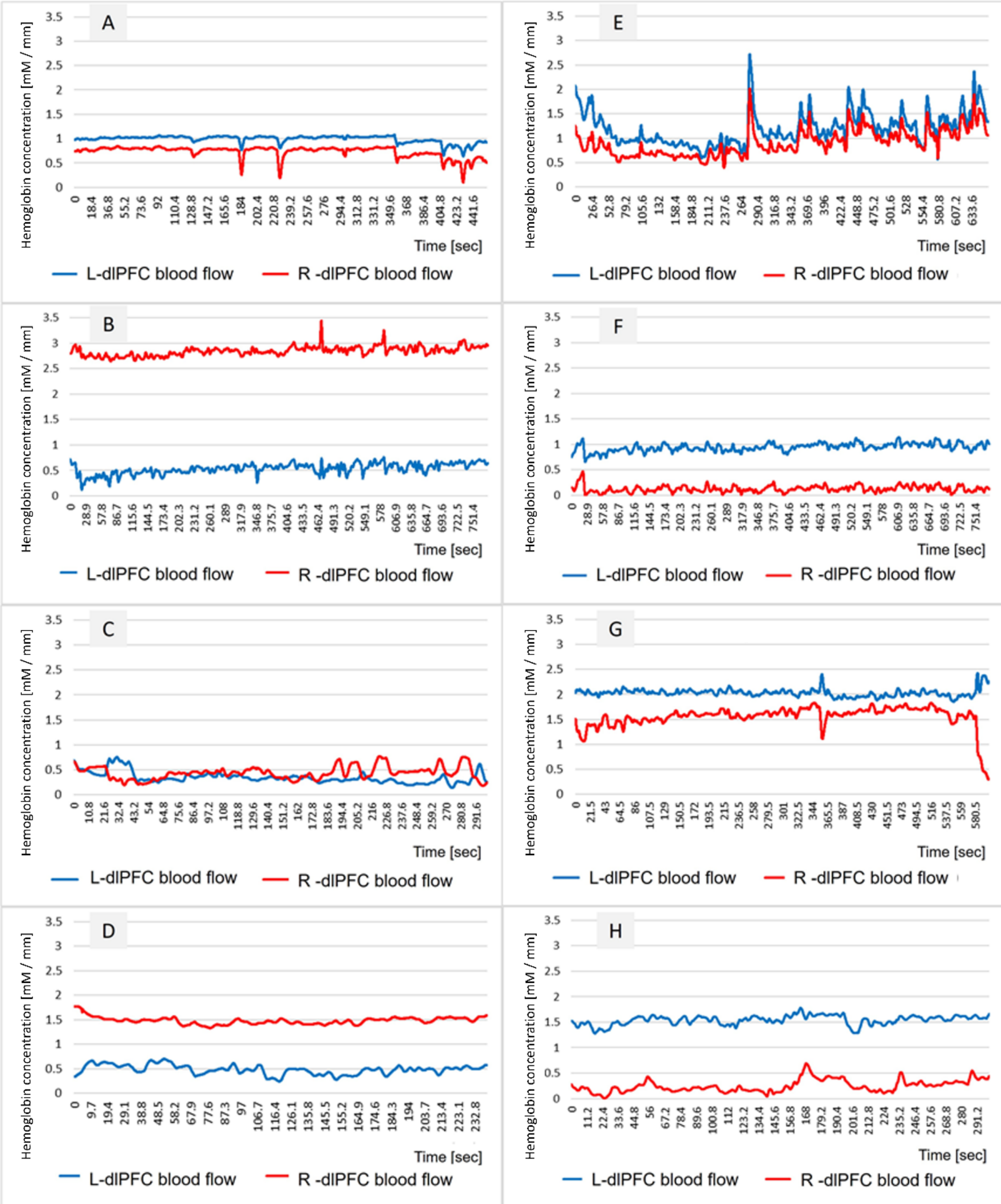

Figure 12. Changes in dorsolateral prefrontal cortex (dlPFC) blood flow during the 2D-3D task. The letters (A–H) in each graph correspond to the participant identification code. Codes were assigned according to participants' total HDS-R scores in ascending order. The vertical axis is the relative change in hemoglobin concentration [mM / mm] when the minimum value at rest is used as the baseline. The horizontal axis is the working time [seconds] for the 2D-3D task. The solid line shows the change in dlPFC blood flow over time. Blue line: left (L)-dlPFC, red line: right (R)-dlPFC.

The waveform data showed that dlPFC blood flow was higher during the 2D-3D task than at rest (Fig. 12). There were three dlPFC blood flow increase patterns on the left and right during the 2D-3D task. In pattern 1, L-dlPFC and R-dlPFC blood flow increased to the same extent (Participants A, C, E). In pattern 2, L-dlPFC blood flow increased more than R-dlPFC blood flow (Participants F, G, H). In pattern 3, R-dlPFC blood flow increased more than L-dlPFC blood flow (Participants B and D). Analysis of L/R-dlPFC blood flow within each pattern shows that the frequency, wavelength, and amplitude of increases or decreases differed. For example, in pattern 1, Participant A's L/R-dlPFC blood flow tended to be almost constant from the start to the end of the task, but decreased temporarily at 184 seconds, 220 seconds, 350 seconds, and 404–440 seconds. Participant C's L-dlPFC blood flow was higher at 21–43 seconds, 270 seconds, and 291 seconds after the start of the task. R-dlPFC blood flow increased gradually from the start of the task to the middle stage and showed a temporary increase after 190 seconds, 200 seconds, 220 seconds, 260 seconds, and 285 seconds. Participant E's L/R-dlPFC blood flow gradually decreased from the start of the task to 200 seconds, after which he had larger increases and decrease in blood flow than participants A and C. Similarly, in other patterns, the amount of increase and the timing of increase in L/R-dlPFC blood flow differed across participants.

3. 2. 3. 3. Relationship between dlPFC blood flow and dementia progression

Figures 13–16 show the variables correlated with L/R-dlPFC blood flow per minute, total HDS-R score, and score for each HDS-R question. L-dlPFC blood flow per minute was negatively correlated with total HDS-R score ($p = 0.038$) and the score for the calculation question in HDS-R ($p = 0.030$) (Figs. 13 and 14). R-dlPFC blood flow per minute was negatively correlated with the score for the delayed recall question in HDS-R ($p = 0.041$) (Fig. 15) and positively correlated with the score for the speech fluency question in HDS-R ($p = 0.007$) (Fig. 16). The score for the immediate recall question was the same for all participants and was therefore excluded from the analysis. No statistical correlations were found among the other items.

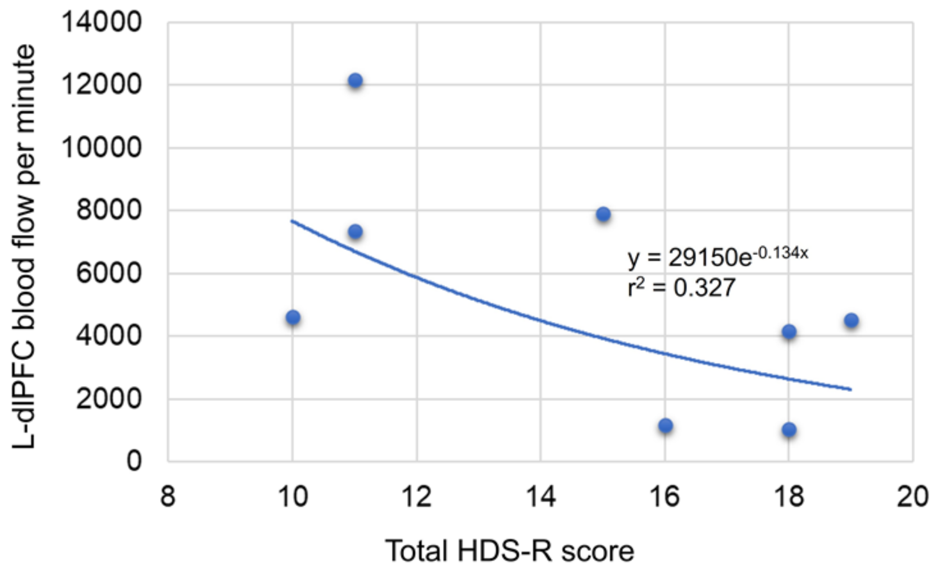

Figure 13. Relationship between left dorsolateral prefrontal cortex (L-dlPFC) blood flow per minute and total Hasegawa's Dementia Scale-Revised (HDS-R) score. Regression equation and correlation coefficient (r) when the dependent variable (y) is L-dlPFC blood flow per minute and the explanatory variable (x) is total HDS-R score.

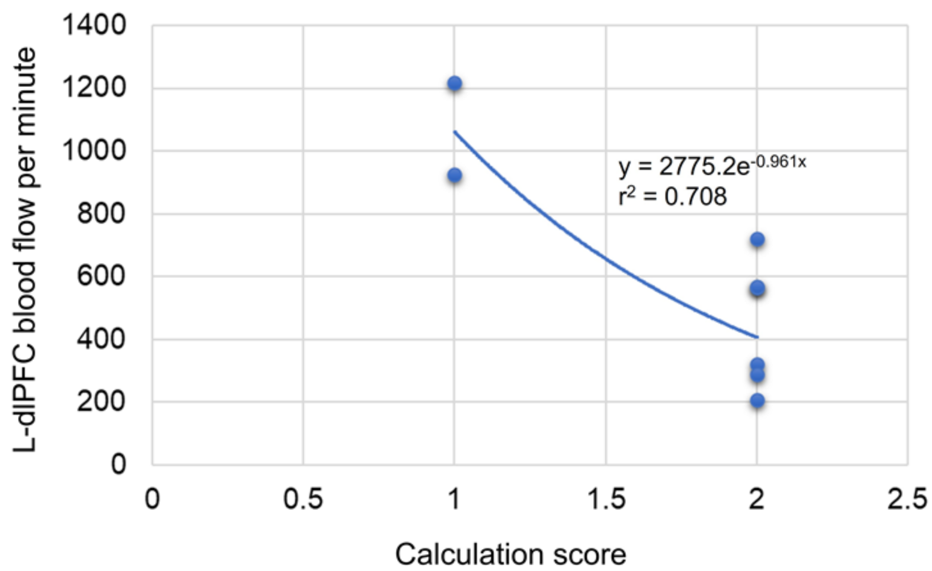

Figure 14. Relationship between left dorsolateral prefrontal cortex (L-dlPFC) blood flow per minute and the score for the calculation question in Hasegawa's Dementia Scale-Revised (HDS-R). Regression equation and correlation coefficient (r) when the dependent variable (y) is L-dlPFC blood flow per minute and the explanatory variable (x) is the score for the calculation question.

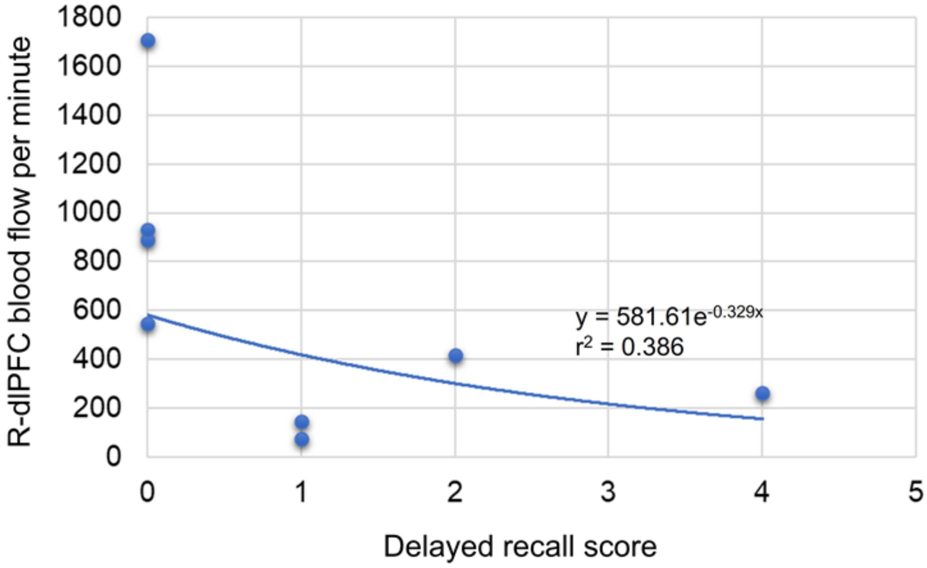

Figure 15. Relationship between right dorsolateral prefrontal cortex (R-dlPFC) blood flow per minute and the score for the delayed recall question in Hasegawa's Dementia Scale-Revised. Regression equation and correlation coefficient (r) when the dependent variable (y) is R-dlPFC blood flow per minute and the explanatory variable (x) is the score for the delayed recall question.

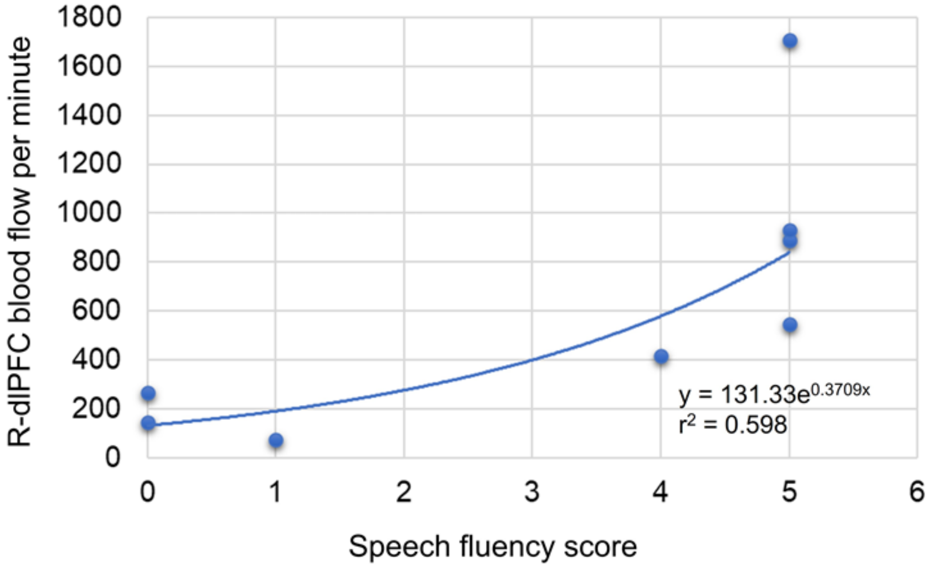

Figure 16. Relationship between right dorsolateral prefrontal cortex (R-dlPFC) blood flow per minute and the score for speech fluency in Hasegawa's Dementia Scale-Revised. Regression equation and correlation coefficient (r) when the dependent variable (y) is R-dlPFC blood flow per minute and the explanatory variable (x) is the score for the speech fluency question.

3. 2. 4 Discussion

3. 2. 4. 1. 2D-3D task participants

Demographic results of the participants showed that patients with mild to moderate dementia can independently complete the 2D-3D task (Table 5). Participants who failed to complete the experiment had slightly severe to severe dementia. Such participants were able to complete the 2D-3D task with assistance from the therapist, such as explanations of the procedure and assistance with physical movements. The main types of support included selecting the type of cut flower, cutting the stem and leaves of the cut flower, verifying if the position of the cut flower in the photo matched the layout of the photo, and pointing to the position of the cut flower to be inserted in the floral form. With these supports, the 2D-3D task was completed by patients with AD who have slightly severe or more severe dementia. Thus, the 2D-3D task can be practiced independently in patients with mild to moderate AD, while patients with slightly severe to severe AD need the support of a therapist. Previous studies have suggested that perceptual decision-making involves individual attention [94]. Since attention deficit is present in patients with AD [95], it is important for the therapist to assist or complement the patient's attention deficit.

3. 2. 4. 2. Effect of the 2D-3D task on dlPFC blood flow

This study clarified that it is possible to increase L/R-dlPFC blood flow with the 2D-3D task (Fig. 11), confirming our hypothesis. In addition, our results were consistent with the findings of a previous study that showed FA increases PFC blood flow in adolescents [72]. It has been reported that dlPFC blood flow decreases at rest and during cognitive function tasks in patients with AD as dementia progresses [77]. Previous studies have suggested that aging-related fragility of blood vessels is associated with the progression of dementia [96, 97]. Since nutritional intake [97, 98] and exercise [99, 100] are effective in improving blood vessels, the 2D-3D task may further increase cerebral blood flow in AD when used in combination with diet and exercise therapy. The effect of the 2D-3D task on increasing dlPFC blood flow is only temporary, during the task. Therefore, in the future, it is necessary to examine whether the progression of dementia can be suppressed when patients with AD continuously perform such functional cognitive tasks. In addition, it is important to verify whether the therapeutic effect is enhanced when used in combination with diet and exercise therapy.

3. 2. 4. 3. Effect of elemental task on L/R-dlPFC blood flow

The amount of increase in L/R-dlPFC blood flow and the timing of the increase differed across participants (Fig. 12). Participants repeatedly performed some elemental tasks during the 2D-3D task. The process of repeating these elemental tasks might increase dlPFC blood flow by a certain amount. Participants had momentarily increased or decreased dlPFC blood flow while repeating these elemental tasks (Fig. 12). For example, in Participant A, L/R-dlPFC blood flow was decreased temporarily at 184 seconds, 230 seconds, 350 seconds, 404 seconds, and 404-440 seconds, but increased at other times. Participant B had R-dlPFC blood flow at 462 seconds and 590 seconds. These findings suggest that the amount of increase in dlPFC blood flow differs depending on the type of elemental work during the 2D-3D task. Since the instantaneous change in blood flow was different every 0.1 milliseconds, it is possible that a specific action during an elemental task is associated with the increase in blood flow. It is possible that the number of actions that activate cognitive functions such as calculation, reasoning, understanding, and planning differed according to each elemental task. In the future, I believe that it will be possible to develop tasks with higher effects by identifying and combining the elemental tasks and movements during functional horticultural tasks that increase cerebral blood flow.

3. 2. 4. 4. Relationship between 2D-3D task-related dlPFC blood flow and dementia progression

L-dlPFC blood flow per minute increased as dementia progressed (Fig. 13). This result was contrary to our hypothesis that dlPFC blood flow during the 2D-3D task decreases as dementia progresses, based on findings from previous study [77]. Our findings are important in that it demonstrates that tasks that activate higher cognitive functions, such as the 2D-3D task, increase dlPFC blood flow even as dementia progresses.

L-dlPFC blood flow during the 2D-3D task increased as the computational cognitive function of patients with AD decreased (Fig. 14). This finding was consistent with previous studies that showed activation of L-dlPFC blood flow during computational tasks [101]. Previous studies have reported that computational cognitive functions are active in the parietal region [102]. The parietal cortex controls visuospatial cognitive function and is correlated with blood flow in the parietal region in patients with AD [103]. While shaping cut flower leaves and stems during the 2D-3D task, it is necessary to compare whether the number of leaves and the length of the stems are the same as those in the provided photographs. When determining where to place cut flowers, it was necessary to calculate the distance of cut flowers from each other and the size of the vase. These processes might have activated the cognitive functions involved in the participants' calculations and increased L-dlPFC blood flow.

R-dlPFC blood flow during the 2D-3D task increased as the cognitive function related to delayed recall decreased (Fig. 15). Cognitive function related to delayed recall involves a series of activities in brain regions such as the bilateral primary motor cortex, bilateral somatosensory cortex, bilateral superior temporal region, precuneus, medial cerebellum, and thalamus region [104]. Furthermore, R-dlPFC blood flow decreased in participants with reduced language fluency (Fig. 16). It has been suggested that speech fluency is involved in cognitive functions such as conflict resolution and monitoring progress [105]. Previous studies have reported that the R-dlPFC controls working memory and attention to words, executive function, planning, reasoning, and cognitive function related to problem solving [106, 107]. I provided the participants with the layout to be reproduced in photographs, but I did not specify the order for reproducing the layout and the procedure for performing elemental tasks. Participants inferred and planned how to perform elemental tasks such as selection of cut flower varieties, moulding cut flower leaves and stems, determination of cut flower arrangement position, and confirmation of overall layout. As a result, R-dlPFC blood flow increased. In the future, it is necessary to study the performance of the 2D-3D task in more patients with AD and accumulate scientific evidence.

Previous studies have suggested that the difficulty (discriminability) and complexity (richness) of perceptual information have a great influence on the cognitive-determining function of dlPFC [108]. In this experiment, the complexity of the 2D-3D task (number and type of plants and tools) was the same for all participants, so the difficulty level involved was the same for all participants. In this section, difficulty level was defined as whether or not the layout can be reproduced in the 2D-3D task. Patients with moderate AD had impaired cognitive function associated with delayed computational and language reproduction. As a result, it is possible that the L-dlPFC blood flow increased as a result of the participant judging that the process of calculating the number and arrangement of cut flowers required to complete the 2D-3D task was difficult. On the other hand, in patients with mild AD, the deterioration of cognitive function related to delayed reproduction of calculation and language was less severe. Therefore, it is possible that the process of calculating the number and arrangement of cut flowers required to complete the 2D-3D task was judged to be less difficult. Patients with mild AD did not have impaired cognitive function in the dlPFC, unlike patients with moderate AD. Therefore, as a result of judging that the difficulty of the work in the 2D-3D task is low, it is possible that the dlPFC blood flow did not increase as much. In the future, I will investigate the relationship between the difficulty of elemental tasks as part of functional horticultural tasks and dlPFC blood flow.

3. 2. 4. 5. Ideal properties of a functional horticultural task

Whether the dlPFC is activated during the 2D-3D task might involve individual decision-making [109]. Previous studies have reported that the cognitive function of the L-dlPFC was activated during positive emotions and that the cognitive function of R-dlPFC was activated during negative emotions [110]. In addition, PFC activity decreases when humans feel a threat [111]. It has been reported that mental conditions such as anxiety and depression are associated with dlPFC inactivation in patients with AD [112]. Chronic psychological stress has also been shown to exacerbate the pathological features of AD in the PFC [113, 114]. Horticultural therapy relieves stress in patients with dementia and in their caregiver [115, 116]. Functional horticultural tasks might be a type of treatment for AD that reduces the mental stress of the patient and caregiver. From the results of this experiment and the reports of previous studies, a functional horticultural task should have five characteristics: (1) clarified treatment goals, (2) based on farming and horticultural work for which patients do not feel threatened, (3) allow patients to use plants and tools with positive emotions, (4) have task difficulty and complexity that the patient can judge to be feasible, and (5) have a verified effect. In future studies, it is important to use brain activity as an index to verify whether dlPFC blood flow in patients with mild AD and ICM can be increased by adjusting the difficulty and complexity of functional horticultural tasks. Since the 2D-3D task increased dlPFC blood flow in patients with mild to moderate AD, the 2D-3D task can be considered to have met these conditions.

3. 2. 4. 6. Limitations of this study

The proportion of female participants in this experiment was high. According to a survey by the Ministry of Health, Labour and Welfare in Japan, as of 2021, women account for approximately 70% of long-term care facility users. Since this experiment was conducted on users of long-term care facilities, most participants were female. Therefore, the 2D-3D task might have an effect on female patients with AD. In future studies, the effects of 2D-3D tasks should be compared by gender.

3. 2. 5. Conclusions

In this section, I showed that a 2D-3D task to activate higher cognitive function in patients with AD increases dlPFC blood flow. During the task, dlPFC blood flow increased more in patients with moderate AD than in patients with mild AD. L-dlPFC blood flow during the task was significantly negatively correlated with the score for the calculation question. R-dlPFC blood flow was significantly negatively correlated with the score for the delayed recall question and positively correlated with the score for the speech fluency question. I concluded that the calculation associated with the elemental task of forming cut flowers and determining the position of cut flowers in the 2D-3D task increased L-dlPFC blood flow. The 2D-3D task also included elemental tasks such as selecting cut flower varieties and confirming the overall layout. Thinking and planning procedures in order to perform those elemental tasks increased R-dlPFC blood flow in patients with AD.

Chapter 4 | A dynamic frameworks for maintaining and continuously improving the quality of horticultural therapy system

4. 1. Applying system dynamics to horticultural therapy

4. 1. 1. Introduction

The number of elderly patients with dementia is increasing worldwide. Dementia is a disease that impairs cognitive functions such as memory, thinking, and decision making [117]. The progression of dementia causes deterioration of psychological and physical functions and interferes with activities of daily living [118, 119]. Early treatment of dementia is important to prevent exacerbation of symptoms.

Horticultural therapy (HT) is a practice aimed at improving the mental and physical functioning of the patient using horticultural tasks. Several previous studies have suggested that people with dementia can improve their mental and physical health by engaging in horticultural programs [116, 120, 121]. Considering that the number of patients with dementia continues to increase worldwide, it is important that HT be widely available in the community.

In many clinical settings, it has been observed that the effectiveness of a horticultural program varies from patient to patient. The therapeutic effect of HT can be influenced by the level of self-efficacy (SE) in a patient. SE is a cognitive self-evaluation that determines how well one can cope with the events one faces [44]. Patients with high SE have higher health-related self-management abilities and faster functional recovery than patients with low SE [122]. In addition, previous studies have shown that increased SE in patients can improve symptoms of anxiety and depression [49]. In HT, the therapist has an important role to establish a horticultural program that increases the patient's SE.

Horticultural therapists need to set horticultural tasks according to the patient's personality traits and design a horticultural program that increases SE. A patient’s SE is regulated by individual personality traits. Personality traits are explained by five categories: neuroticism, openness, agreeableness, conscientiousness, and extraversion. Previous studies have reported that a high SE are regulated by these personality traits [123].

The horticultural therapist needs to have an accurate understanding of the relationship between the therapist and the patient in order to set the optimal task considering the patient's SE and personality traits. Horticultural therapists have historically set up horticultural tasks according to their experience. However, since there are various types of horticultural tasks and personality traits, it is difficult to determine the optimal combination of tasks and traits based on the experience of the therapist alone. A systems approach (systems thinking/system dynamics) is a methodology used to solve complicated problems caused by such variable factors. Systems thinking is a methodology that considers complex events as a system and models the elements involved and the causal relationships between the elements. System dynamics is a methodology that can quantify changes in elements over time by adding a time axis to the model. These are also used to solve complex problems in biology and medicine [124-127].

In this section, I applied the systems approach to HT to build a dynamic model in order to visually and temporally understand the relationship between the therapist and the patient. I also used this dynamic model to describe how the therapist could set up a horticultural task that was appropriate for the patient's SE and personality.

4. 1. 2. Methods

4. 1. 2. 1. Applying systems thinking

Three steps were taken to apply systems thinking to HT: (a) description of the systematic basic structure of HT, (b) extraction of components related to the system, and (c) schematization of causal relationships between multiple components.

(a) Systematic basic structure of HT

The systematic structure was described from the findings obtained from clinical practice and observation of HT. HT begins with the therapist understanding health-related information such as the patient's illness, mental and physical function, personality traits, preferences, and treatment goals. Next, the therapist sets the optimal horticultural task based on health-related information. The therapist provides the task to the patient. The patient carries out the task based on the degree of SE they possess relative to the task. From the patient's activity, the therapist evaluates the qualitative and quantitative indicators of the patient's physical and mental functions. Based on the evaluation, the horticultural therapist sets a new horticultural task according to the patient's functional recovery. As mentioned above, the practice of HT is centered on the therapists and patients. I hypothesized that the therapist and the patient each function as a subsystem, and that the combination of the two subsystems is the systematic basic structure of HT.

(b) Extracting components

In systems thinking, if the number of components contained in a system is extremely large, the system becomes complicated and it becomes difficult to understand the relationships among the components. Conversely, if the system is extremely small, it becomes an impractical system structure. In this section, I have extracted the minimum components necessary to express the relationship between the therapist and the patient in HT.

(c)-1. Description of the therapist subsystem and components

The main role of the therapist subsystem is to select a horticultural task based on the patient's health-related information and adjust the complexity of horticultural tasks. Whether the horticultural task increases a patient's SE depends not only on the patient's personality, but also on the complexity of the task [59, 128]. Complexity is an objective characteristic of a task, which has attributes such as the amount, diversity, and rate of change in information [129]. It is also said that the complexity of the task increases as each attribute increases. In this paper, the objective characteristics of tasks in HT are the plants and tools used in the horticultural task, and the attributes are defined as their shape and size, color, amount and variety of aromatic components, and rate of change. Furthermore, I defined a horticultural task in which the therapist changed the complexity of the horticultural task according to the patient's SE and personality traits. Based on the above, the basic components of the therapist system were set as "horticultural task," "adjustment of horticultural task complexity," and "qualitative/quantitative evaluation" of the patient's SE.

(c)-2. Description of patient subsystem and components

The main role of the patient subsystem is to perceive/recognize horticultural tasks and act based on their SE. Therefore, the components are set as "perception," "cognition," "SE," and "activity." Cognition is controlled by dementia, and SE is controlled by personality traits, experience, and general mental ability. Therefore, "dementia," "neuroticism," "openness," "agreeableness," "conscientiousness," and "extraversion" were set as control factors. Judge et al (2007) reported that task-related experience and general mental abilities were associated with other factors affecting SE [123]. Therefore, "experience" and "general mental ability" were also set as control factors.

(c)-3. Explanation of causal relationships between components

In HT, the therapist provides the patient with a horticultural task, and the patient performs the task. The therapist progresses the treatment by qualitatively/quantitatively assessing the patient's activity. Therefore, I hypothesized that the therapist subsystem and the patient subsystem interact cyclically (Fig. 17).

4. 1. 2. 2. Apply system dynamics

Using Stella Architect, numerical values were assigned to the components of the static model, and equations were assigned to the causal relationships between the components (a). Latent variables indicating the initial conditions for starting HT were set for these numerical values and equations (b). In this section, the minimum value of the latent variable is set to 0 and the maximum value is set to 100. By this procedure, the static model of HT was transformed into a dynamic model.

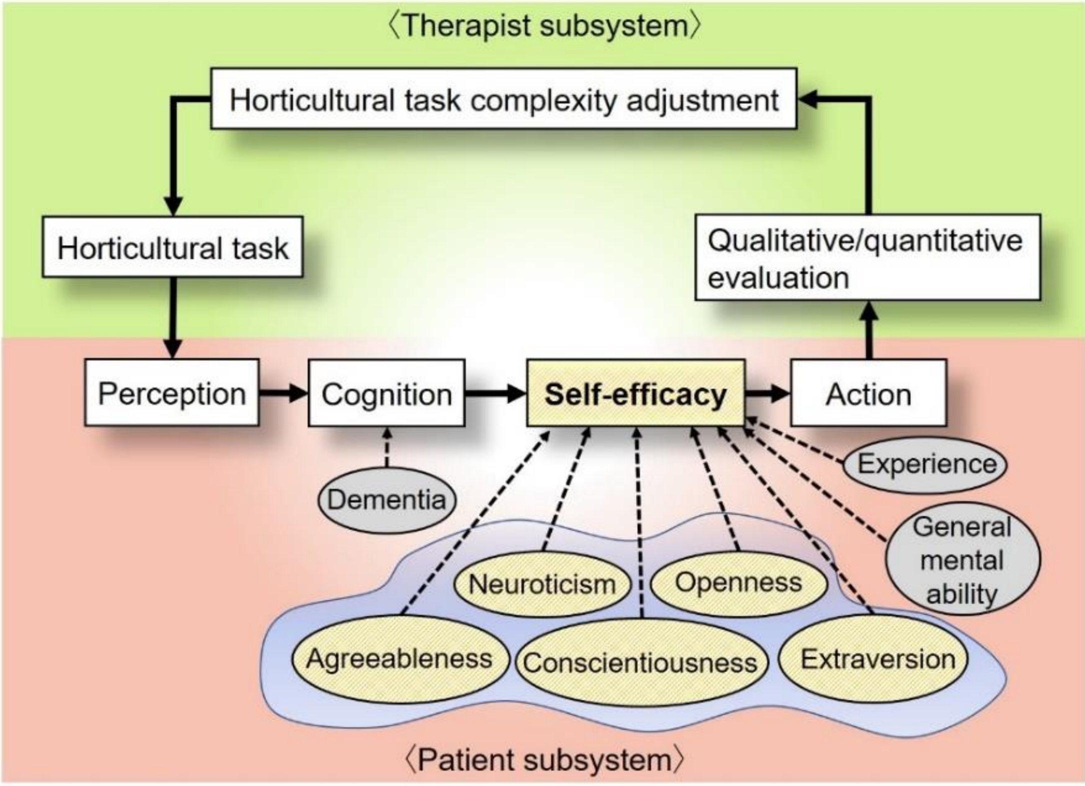

Figure 17. Static model of horticultural therapy. The green background shows the therapist subsystem, and the orange area shows the patient subsystem. Squares, circles, lines, and broken lines are the components, control factors, causal relationships between components, and the effects of control factors, respectively, in the static model.

(a) Equation settings

The therapist first sets the level of task complexity according to the initial value of the patient's SE. Patient SE is known to increase at moderate to low levels of task complexity rather than at high levels. After that initial setting, I set “Adjustment of horticultural task complexity” as the square of SE to gradually increase the complexity of the horticultural task as the patient's SE increased (Equation 1). The exponentiation can be changed to 1.2 or 1.5 according to the patient's desired treatment period, that is, the speed of treatment.

The patient's perceptual probability is related to the functions of sight, smell, hearing, touch, and taste. This time, it was assumed that the patient's perception was healthy and 100% of the information on the complexity of the horticultural task was input. Therefore, the perceptual probability was shown by the numerical value of the horticultural task whose complexity is adjusted (Equation 2). If the patient has a disorder associated with reduced perceptual probability, the number of horticultural tasks should decrease. In that case, it should be possible to solve it by setting new components that represent the functions of the five senses and including their influence indexes.

Probability of cognition indicates that some of the perceived horticultural task information is lost due to dementia. To show this, Equation 3 sets the degree of dementia progression with respect to the perceived information on the horticultural task. According to the dementia evaluation method "Hasegawa's Dementia Scale Revised Edition（HDS-R）, " which is generally used in Japan, dementia is diagnosed when the score is 20 or less out of a maximum of 30 points. In this section, I have shown it as "dementia / 100" to show that I am using the scale of latent variables I set (Minimum value 0, Maximum value 100). In the "dementia" part, the evaluation value of the patient evaluated by the therapist is shown, but this is also converted to the scale of the latent variable and then substituted.

Changes in self-efficacy and probability of acting are controlled by their personality traits and experience, as well as general mental functioning. Their relationship was set using the impact index reported by Judge et al (2007). In general, a patient's personality traits, experience, and general mental function are evaluated using a dedicated evaluation scale. Equations 4 and 5 were set up for therapists to incorporate the patient values evaluated by them into a static model of HT. The setting method is the same as the content explained in equation 3.

$$\text{Horticultural task complexity adjustment} = \text{Self-efficacy}^2 \quad (1)$$

$$\text{Probability of Perceiving} = \text{Horticultural Task} \quad (2)$$

$$\text{Probability of Recognition} = \text{Perception} \times \text{Dementia}/100 \quad (3)$$

$$\text{Change in Self-efficacy} = \text{Cognition} \times \{(\text{Neuroticism} \times 0.21 + \text{Openness} \times 0.11 + \text{Agreeableness} \times -0.05 + \text{Conscientiousness} \times 0.19 + \text{Extraversion} \times 0.29 + \text{Experience} \times 0.26 + \text{General Mental Ability} \times 0.17)\ /100\} \quad (4)$$

$$\text{Probability of Acting} = \text{Self-efficacy} \times \{(\text{Neuroticism} \times -0.04 + \text{Openness} \times -0.04 + \text{Agreeableness} \times 0.05 + \text{Conscientiousness} \times 0.26 + \text{Experience} \times 0.26 + \text{Extraversion} \times 0.09 + \text{General Mental Ability} \times 0.52)\ /100\} \quad (5)$$

(b) Latent variable settings

The initial conditions of HT were set by substituting latent variables for each component. The initial value of the complexity of the horticultural task was set to 1, because I assumed that the patient had an initial SE value of 2. Perception, cognition, SE, and action increase or decrease under the influence of the horticultural task, so the initial value was set to 0. According to the HDS-R, dementia is diagnosed when the score is 20 or less out of a maximum of 30 points. Since all latent variables were set to 100 in this example, the initial value of dementia was set to 60, which indicates mild dementia. The patient's personality traits were described in the simulation conditions section because the numerical values were changed according to the two scenarios during the simulation.

4. 1. 2. 3. Simulation conditions

I simulated the relationship between the therapist and the patient over time, assuming that the patient with dementia was given HT for 12 months. The values of the latent variables assigned to the dynamic model set the scenario conditions of two patients with different personalities, experiences, and general mental functions. In order to visually understand that the task settings, in this case, were different due to the different control factors, the latent variables were assigned extremely different numerical values. In the first session, I set a latent variable of 50, which indicates moderate-functioning personality, experience, and general mental function when evaluated at a maximum of 100 (scenario A). For the second session, I set a latent variable of 10 that indicates that these control factors are lower functioning than in scenario A (scenario B).

4. 1. 3. Results and discussion

4. 1. 3. 1. Dynamic model of Horticultural therapy

By applying the systems approach to HT, the relationship between the therapist and the patient could be visualized as a time-dependent system model (Fig. 18). Historically, therapists have understood patient health-related information through experience or text-based information. These factors vary from individual to individual and can lead to risks in interpretation such as inconsistencies and inaccuracies in treatment methods. The dynamic model I created this time can visually understand the state of mental and physical function of patients, the direct effects of diseases, and therapeutic targets. By using this dynamic model in clinical practice, it may be possible to visually understand patient health-related information, prevent inconsistencies in understanding among therapists, and facilitate information sharing.

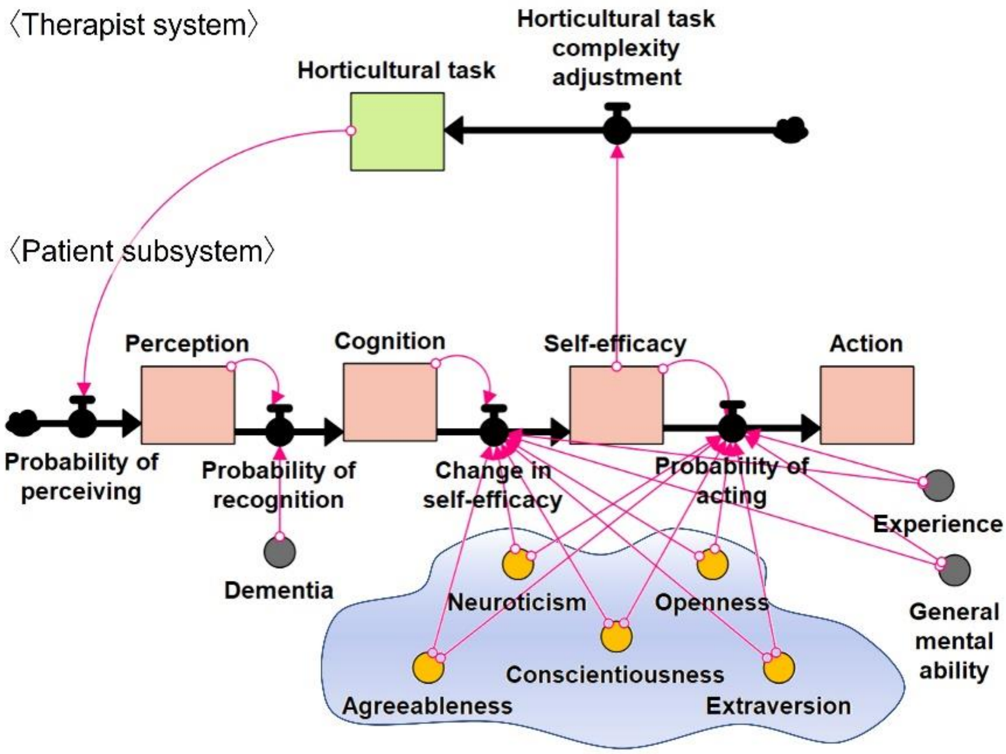

Figure 18. A dynamic model of horticultural therapy. Squares, circles, black arrows, and pink arrows indicate components, control factors, causal relationships between components, and control factors, respectively.

4. 1. 3. 2. Quantitative relationship between the horticultural therapist and patient

Simulations using a dynamic model of HT quantitatively showed the optimal horticultural task for patients with different personality traits, experiences, and general mental functions (Fig. 19). The simulation results under the two scenario conditions predicted the complexity of the horticultural task optimal for the personality traits of the patients. In addition, it showed that the patient's SE gradually increased every three months as the therapist continued to provide the optimal task to the patient.

The simulation results showed that it was necessary to change the setting of the horticultural task after the third month according to the difference in the personality traits of the patients. In previous studies, HT was often practiced between 3 and 6 months [116, 120, 121, 130]. In addition, other studies have reported that practicing HT for 12 months had no effect [131]. The results of scenario A suggest that SE increases by increasing the complexity of the horticultural task after the third month. However, scenario B suggests that the same procedure should be performed after the sixth month. For example, in a FA task, increasing the number of cut flowers increases the complexity. People who have experience in FA can easily perform the task even if there are many types and numbers of cut flowers, but those who have no experience can be confused. In the latter case, it is important for the therapist to deliberately reduce the type and number of cut flowers to reduce complexity. Using the Stella Architect's program, such predictions can be made by simply hovering the mouse cursor over the personality trait icon and moving the cursor to the desired numerical values (Fig. 20). If the rate of increase in SE differs from the predicted value due to other western medical treatments or social psychological effects other than HT, the value can be input to the dynamic model for re-simulation. A dynamic model of HT is a dynamic framework for therapists to proceed with treatment like the Plan-Do-Check-Act (PDCA) cycle. It will help horticultural therapists and researchers determine the optimal horticultural task from the patient's personality traits. These predictions are new hypotheses that have not been discussed in previous studies, demonstrating the importance of applying the systems approach to HT.

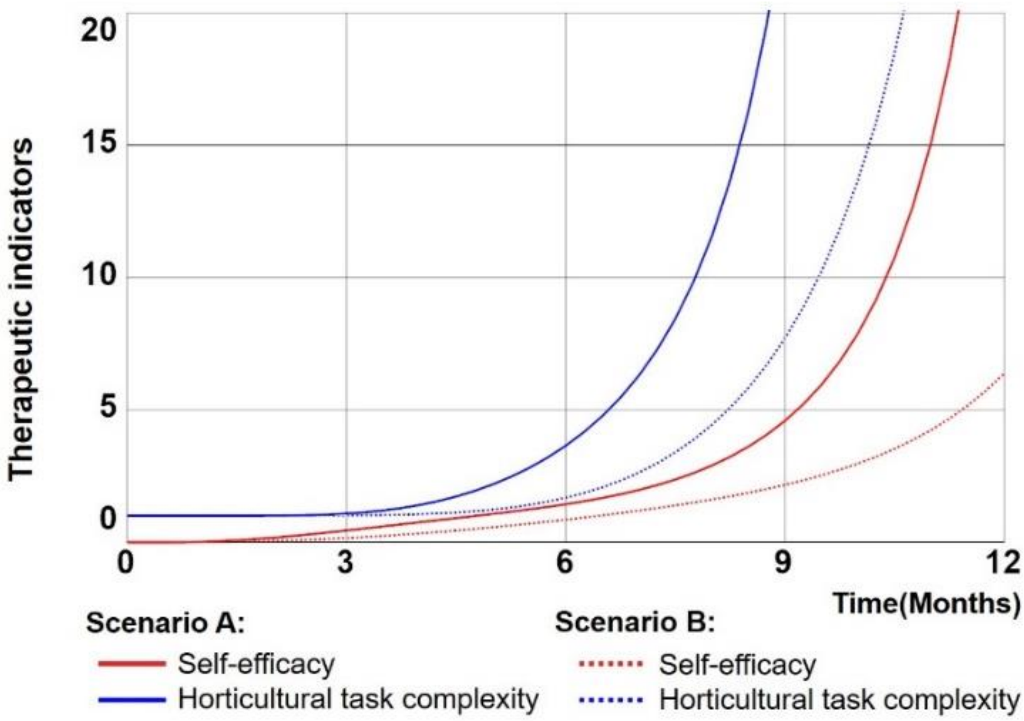

Figure 19. Results of a 12-month HT simulation using a dynamic model. The vertical axis shows the treatment index and the horizontal axis shows the treatment time. Therapeutic indicators mean clinical indicators and the effect indicators have for improving the quality of treatment. Here, the complexity of horticultural work is shown by the blue line as clinical indicators, and the high self-efficacy of the patient is shown by the red line as effect indicators. The solid line for each color shows the result of scenario A, and the dotted line shows the result of scenario B.

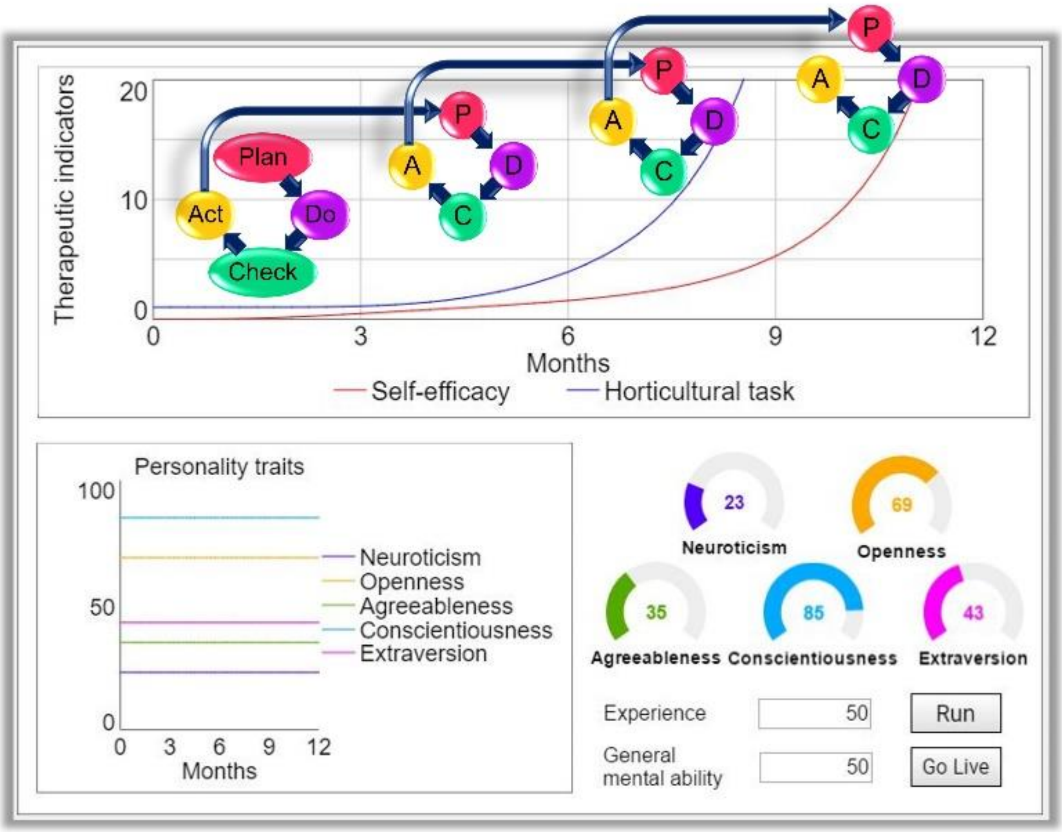

Figure 20. Screenshot of Stella Architect accessories. You can start the simulation by pressing the "Run" button. The simulation results are shown in the table above. The value of the patient's personality trait can be changed by the following procedure. Press the "Go live" button→ Place the mouse cursor on the icon of the personality trait you want to change, and change the value while left-clicking. The changed values are shown in the table at the bottom left. After the setting is completed, the simulation can be started under the new personality trait condition by pressing the "Run" button again.

In this section, I created a dynamic model of HT focusing on dementia. When using such a dynamic model for other diseases, it is necessary to appropriately change the number and type of components according to the patient's disease and physical characteristics. In clinical trials, it may be possible to perform more accurate simulations by substituting values and mathematical formulas that evaluate the patient's health condition qualitatively and quantitatively, rather than using latent variables in the dynamic model. However, it is important to understand that the true purpose of using dynamic models is not to produce accurate prediction results. I consider it a tool to visualize invisible mental changes in the patient and help therapists decide how to treat them. Even if the dynamic model is modified according to the patient's characteristics, I believe that the basic structure of HT to support the patient's health is the same. It is a continuous cycle of positive improvement, with each task building on the previous one: (1) the therapist selects a horticultural task that suits the patient's illness, physical and mental condition, and preferences; (2) the therapist provides the patient with a horticultural task and adjusts the complexity of the horticultural task according to the patient's SE and personality traits; (3) the patient recognizes the task; (4) the patient acts based on their degree of SE; (5) the therapist qualitatively and quantitatively assesses the effect of the horticultural task; and (6) the therapist selects the next horticultural task to increase the patient's SE. A key part of the therapist's role is to prepare conversations, plants, tools, and practical environments (temperature, humidity, and location) to support a continuous cycle of progression for the patient. I also speculate that these potential effects will lead to improved physical function and the creation of a community.

4. 1. 4. Conclusions

It is known that in most HT practice sites, there are individual differences in the effectiveness of horticultural programs. Cognitive function, which is one index of the therapeutic effect, is controlled by the patient's SE and personality traits. The purpose of this study was to examine a method for setting horticultural tasks appropriate for the patient's SE and personality. First, I applied systems thinking to HT and created a static model that describes the systematic structure of the therapist-patient relationship. Next, using Stella Architect, the static model was transformed into a time-dependent dynamic model. The model provides a visual and timely understanding of the patient's physical and mental condition, the effects of the disease, and the therapeutic target. Finally, a simulation was performed using the model. The results quantitatively showed the complexity of horticultural tasks appropriate for the patient's personality. Furthermore, our results suggest that patient SE could be increased by gradually increasing the complexity of horticultural tasks as the treatment progresses. In the future, the accuracy of simulation results may be improved by substituting clinically obtained measurements into the dynamic model. It may help the therapist set up a horticultural task that is appropriate for the individual's personality and increase the patient's SE.

4. 2. Applying the PDCA cycle to horticultural therapy

4. 2. 1. Introduction

The effects of horticultural programs used in horticultural therapy are slow-acting and require long-term intervention. Generally, horticultural programs are developed based on group work and are used for improving sociality and rehabilitation. In previous studies, a static framework was created to support program development, and the functional recovery effect of horticultural programs has been verified. However, it is known that the speed of recovery of human mental and physical functions depends on the individual's self-efficacy for treatment. This suggests that when using a horticultural program for functional recovery, it is necessary to improve the content of the program according to the speed of individual functional recovery.

In the manufacturing, service, and education fields, the PDCA cycle is a method for improving the quality of services appropriately and over time. P means planning, D means execution, C means evaluation, and A means improvement. This is a project management method devised by William Edwards Deming. In the medical field as well, the PDCA cycle is used as a methodology for improving the quality of services such as treatment and nursing [132, 133]. I apply the PDCA cycle to horticultural therapy and plan the horticultural program (P), provide it to patients (D), evaluate the effect of the program (C), and improve the program (A). I thought that I could provide high quality support.

In this section, I devised a dynamic framework for circulating the PDCA cycle over time for the treatment of horticultural therapy. I also summarized the criteria for the therapist to make rational decisions when circulating the PDCA cycle. This is because if the therapist makes an inappropriate change to the program, there is a risk that the effect will be reduced. Here, I propose PDCA cycle treatment as a new treatment methodology for horticultural therapy and discuss its usefulness.

4. 2. 2. Method

4. 2. 2. 1. Applying the PDCA cycle to horticultural therapy

In the conclusion of the previous section, I described that the dynamic model of HT helps determine the optimal horticultural task from the patient's personality traits [134]. In this section, a dynamic framework was constructed for long-term and planned treatment tailored to the personality traits of individual patients using the dynamic model.

First, from the viewpoint of the PDCA cycle, the practical content of HT was classified into Plan, Do, Check, and Act, and long-term treatment improvement methods were explained (Fig. 21). Next, a new therapeutic framework was proposed that systematically circulates the PDCA cycle using a dynamic model.

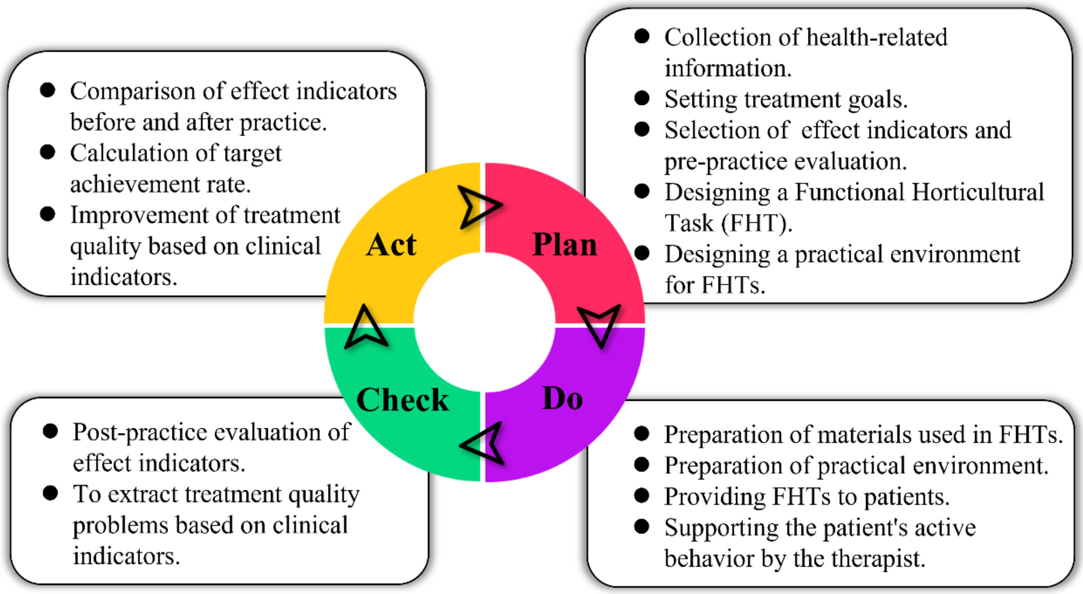

Figure 21. PDCA cycle in HT and its outline. "Plan" means planning a functional horticultural task by a horticultural therapist, "Do" means practicing the functional horticultural task, "Check" means evaluating the effect, and "Act" means improving the treatment plan. Horticultural therapists can improve treatment plans in a rational and long-term manner by circulating this PDCA cycle based on rational decision making.

(a) Plan

- **Collection of health-related information**

The therapist obtains health-related information such as the patient's age, medical history, occupation, medical/welfare services available, and family structure through structured or unstructured interviews and observations. The International Classification of Functioning, Disability, and Health is used as an index to help obtain that information. The items include indicators for analyzing physical function and disability for daily life, and social activity and participation status. In addition to that item, the horticultural therapist acquires information on hobbies and tastes in order to bring out the patient's high SE.

- **Setting treatment goals**

After learning the patient's health-related information, set the patient's treatment goals. In many cases, the treatment goal of the patient is to improve mental illness and dementia. Horticultural therapists should use effect indicators that objectively show the effectiveness of functional horticultural tasks in order for patients to know how well they have achieved their treatment goals. In the next section, I have listed some measures used as effect indicators.

- **Selection of effect indicators and pre-practice evaluation**

A scale such as the Depression Anxiety Stress Scale (DASS21) is used to objectively measure mental illness, and the Mini-Mental State Examination (MMSE) is used for dementia. In general, changes in these indicators appear slowly, so indicators that can be used to investigate immediate effects are evaluated. The following are candidate indicators for assessing effects on mental, cognitive, and physical function.

(a) Mental effect index

Qualitative indicators: Self-efficacy scale, Big Five scale, Profile of Mood States, The State-Trait Anxiety Inventory, Likert scale
Quantitative indicators: Electroencephalogram, heart rate, salivary cortisol, salivary amylase, cerebral blood flow

(b) Cognitive effect index

Qualitative index: Mini Mental State Examination, Hasegawa Dementia Rating Scale-Revised
Quantitative: Cerebral blood flow, neuroimaging

(c) Physical function effect index

Qualitative index: activity amount and muscle strength in one horticultural task, activity content, range of motion of arms and legs, care level, frequency of participation, frequency of interaction, number of conversations, frequency of going out, facial expression analysis (frequency of smiles)
Quantitative indicators: blood, respiratory volume, muscle strength, calories burned, metabolic equivalents (METs)

Q & A type effects indicators require active patient participation. With heavy use of these types of indicators, patients take a long time to answer questions and they can be psychologically or physically burdensome. To reduce the patient's mental and physical load, it is important to limit the number of effect indicators to the minimum necessary to assess the achievement of treatment goals, rather than unnecessary use.

- **Designing a functional horticultural task**

Horticultural therapists need to design functional horticultural tasks to circulate perception → cognition→ high SE→ action based on patient health-related information, treatment goals, and practical environment. The design method of this task is explained in Chapter 2, and the more specific method is described in Methods of Experiment 1 and Experiment 2 in Chapter 3.

- **Designing a practical environment for functional horticultural tasks**

The horticultural therapist needs to confirm in advance whether the environment in which the horticultural task is performed is a condition that does not deteriorate the health condition of the patient. Its basic environmental conditions include the place of practice (indoors and outdoors), weather, temperature, humidity, light intensity, and the presence of animals and insects. In the practice of outdoor horticultural tasks, heat stroke is the most dangerous risk, and it is necessary to take measures such as regular hydration and securing a shaded area. If the patient is at risk of falling due to steps or slopes, assistive devices such as handrails and wheelchairs should be prepared in advance.

(b) Do

- **Preparation of materials used in functional horticultural tasks**

Prepare the plants and tools necessary to carry out the functional horticultural task in the practical environment of the functional horticultural task. The preparations should be positioned so that the patient can complete the functional horticultural task. When the patient is sitting in a wheelchair if the planter for planting the plant is prepared below the patient's knees, it will be difficult to perform the task. The importance of the positional relationship between the patient and the materials used in the functional horticultural task is described in detail in Chapter 2.

- **Preparation of practical environment**

Reproduce the environment for practicing pre-planned functional horticultural tasks. Horticultural therapists should prepare multiple tools and aids to accommodate changes in the patient's mental and physical health. For example, in a plant irrigation task, a watering can or hose that holds 5 to 10 liters of water is used as a container for water. However, for patients with weak muscles, a 500 mL PET bottle should be prepared as an auxiliary tool. In the work of plowing soil, shovels, scoops, spoons, and other tools of different shapes and weights are prepared. It is important for the horticultural therapist to prepare multiple tools and aids so that the patient can independently complete the functional horticultural task.

- **Presenting functional horticultural tasks to patients**

The horticultural therapist provides orientation and guidance before presenting the patient with a functional horticultural task. The content of the orientation is self-introduction of the horticultural therapist and the patient. The purpose of self-introduction is to build trust between the horticultural therapist and the patient. The content of the guidance is to provide information on the content of functional horticultural work, the physiological characteristics of the plants used, and cultivation techniques.

- **Supporting the patient's active behavior by the therapist**

Basically, functional horticultural tasks are designed by horticultural therapists to allow patients to complete the task independently. However, if the design is not optimized for the patient, the patient may not be able to work on the functional horticultural task independently. For example, when a 2D-3D task was provided to a patient in a clinical setting as in Experiment 1 in Chapter 3, there was a patient who could not insert a cut flower into a water-absorbent sponge due to weakened arm muscle strength. In that case, the horticultural therapist was in charge of assisting the patient in holding the cut flower and inserting the cut flower. Horticultural therapists need to play a role in speaking and physically assisting the patient in the face of such irregular situations in which the patients are unable to complete functional horticultural tasks.

(c) Check

- **Post-practice evaluation of effect indicators**

In order to evaluate the effect of the functional horticultural task on the patient, the health condition after the experiment is re-evaluated using the effect indicator that evaluated the health condition before the practice. At this time, it is important to make a list of the date and time of the pre-practice evaluation, the date and time when the functional horticultural task was started, its frequency and period, and the cost. Such information is useful in presenting patients and WM professionals with the duration and cost-effectiveness of HT treatment.

- **To extract treatment quality problems based on clinical indicators**

Based on the clinical indicators, the horticultural therapist extracts the problems that occurred while the patient was practicing the functional horticultural task and the problems related to the support of the horticultural therapist. A clinical indicator refers to an objective indicator for improving the quality of treatment. Clinical indicators in HT include the types of functional horticultural tasks, the difficulty and complexity of each task, the content and frequency of horticultural therapist support, physical assistance methods, and cost-effectiveness. For example, there was a case where a cut flower could not be inserted into a water-absorbent sponge because the patient's muscle strength was weak. The practice leads to the following remedies for the difficulty of functional horticultural tasks; reduce the hardness of the water-absorbent sponge or make holes in the water-absorbent sponge in advance to make it easier to insert cut flowers. Finding treatment problems based on clinical indicators helps horticultural therapists consider specific steps to improve the quality of HT.

(d) Act

- **Comparison of effect indicators before and after practice**

The horticultural therapist compares the health indicators evaluated by the patient before and after performing the functional horticultural task to see if their health has improved. If there is no difference in the comparison results, it indicates that the health condition was maintained. If the health condition deteriorates after the practice, it means that the functional horticultural task was ineffective or worsened the condition. If the health condition improves, it indicates that the functional horticultural task was effective. If the functional horticultural task is not effective, it is necessary to improve the extracted problems and the functional horticultural task.

- **Calculation of target achievement rate**

To better understand the effects of functional horticultural tasks, it is advisable to calculate the treatment achievement rate (%). The treatment achievement rate can be calculated by dividing the effect indicator value set as the patient's treatment goal by the effect indicator value at a certain point in time and multiplying by 100 (Equation 6).

$$Treatment\ \ achievement\ \ rate = \left(\frac{Effect\ \ indicator\ \ value\ \ at\ \ a\ \ certain\ \ point\ \ in\ \ time}{Effect\ \ indicator\ \ value\ \ set\ \ as\ \ the\ \ patient's\ \ treatment\ \ goal}\right) \times 100 \tag{6}$$

For example, the treatment goal is 10 and the effect indicator value of the patient before practice is 2. By substituting this value into Equation 6, the treatment achievement rate is calculated to be 20%. If the effect indicator value is 8 after practicing the functional horticultural task, the treatment achievement rate is calculated to be 80%. If this calculated value reaches 100%, it indicates that the treatment is complete, and if it is less than that, it indicates that the functional horticultural task needs to be continued.

- **Improvement of treatment quality based on clinical indicators**

Functional horticultural tasks are improved based on the list of problems extracted in the Check. At this time, the horticultural therapist can use a dynamic model of HT to simulate the effect of the improved functional horticultural task on the patient's effect indicator. By designing and improving functional horticultural tasks using the simulated values as an indicator of rational decision-making, the quality of treatment can be systematically improved. In the next section, I described specific methods for clinical indicators of the PDCA cycle using a dynamic model of

HT.

4. 2. 3. A dynamic framework for continuous improvement of treatment plans based on the rational decision-making of horticultural therapists

Section 1 of Chapter 4 described how to use the HT dynamic model to quantify effect indicators such as SE height and clinical indicators for functional horticultural tasks. This section described how horticultural therapists can use the HT dynamic model to improve and redesign functional horticultural tasks in a long-term and systematic manner based on rational decision making. If the contents of each section are shown in the PDCA cycle of HT, Section 1 uses the HT dynamic model as a tool for "check", and Section 2 uses it as a tool for "Do" and "plan".

Here, horticultural therapists have shown how to use the HT dynamic model to advance treatment while improving the complexity of functional horticultural tasks in response to changes in the patient's five personality traits. The method of proceeding with treatment by circulating the PDCA cycle was named PDCA cycle treatment.

In PDCA cycle treatment, regular evaluation of patient personality traits and clinical indicators is required to improve functional horticultural tasks in response to changes in patient personality traits. Since changes in the patient's personality traits occur slowly, it may be appropriate to evaluate once every 1 to 3 months.

This time, a specific example of PDCA cycle treatment assuming that HT will be performed for 12 months for patients with dementia was explained. The changing patient personality trait was "conscientiousness" and the clinical indicator was the complexity of the functional horticultural task. The patient's conscientiousness is evaluated once every three months, and the functional horticultural task is improved according to the value. At this time, I assumed a scenario in which conscientiousness increased by 3 points every 3 months.

The first step in PDCA cycle treatment is to substitute the numerical values that indicate the patient's prerequisites into the dynamic model.

(a) Initial value of HT dynamic model

- Disease: Dementia = 60
- Health: Perception = 1, Cognition = 0, SE = 0, Action = 0
- Five personality traits: Neuroticism = 10, Agreeableness = 10, Conscientiousness = 10, Openness = 10, Extraversion = 10, Experience = 10, General mental state = 10

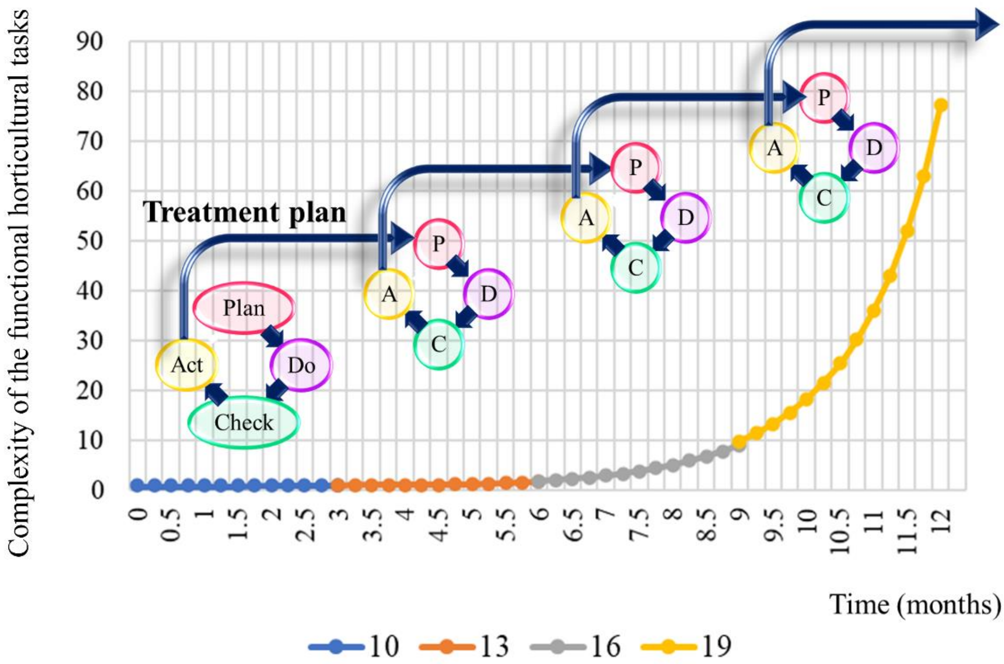

Figure 22. Functional horticultural task complexity and treatment planning in response to changes in client “Conscientiousness” generated by the dynamic model of HT. The horizontal axis shows the duration of treatment and the vertical axis shows the complexity of the functional horticultural task. The blue, orange, gray, and yellow markers are the client's "Conscientiousness" values every three months. The line shown in the line graph shows the complexity of the functional horticultural task predicted according to the value of "Conscientiousness." The PDCA cycle treatment shown in this figure means that the treatment plan is improved every 3 months.

As the next step, the numerical value of conscientiousness evaluated every 3 months is substituted into the dynamic model and simulated. The prediction results are shown in Fig. 22. The results show that the complexity of the functional horticultural task needs to be gradually increased as the patient's conscientiousness changes to 10, 13, 16, and 19 every three months.
By using a dynamic model of HT, horticultural therapists can rationally improve functional horticultural tasks and treatment plan using prediction results as decision-making indicators.

4. 2. 4. Conclusions

The dynamic model of HT can predict the optimal functional horticultural task complexity according to the patient's disease, physical condition, and changes over time in the five personality traits. This predicted value can be treated as an index for the horticultural therapist to rationally improve the treatment plan. Horticultural therapists may be able to provide more effective functional horticultural tasks according to the patient's physical condition by performing PDCA cycle treatment using a dynamic model of HT. PDCA cycle treatment may serve as a dynamic framework for rational and long-term improvement of HT treatment plans. In the future, it is necessary to verify whether PDCA cycle treatment can actually be used in clinical practice and its usefulness.

Chapter 5 | Concluding remarks

5. 1. Key points of this research and future prospects

Based on systems thinking, I constructed a system model that illustrates the mechanism of action of HT. This model visually showed that the purpose of HT treatment is to circulate patient perception→ cognition→ high SE→ action (active behavior) through gardens and horticulture and increase high SE. As a method to achieve this, it was pointed out that it is important to use affordances that elicit the active behavior of patients by using the physical characteristics of gardens and horticulture. Physical features include the size, weight, shape, and aroma components of plants and tools. In the future, it will be necessary to accumulate physiological and cytological scientific evidence regarding the relationship between these physical characteristics and the perception, cognition, and behavior of patients.

Based on the HT system model, I devised a functional horticultural task (2D-3D task) to increase dlPFC blood flow in dementia patients. As a method to verify the effect, I adopted the experimental protocol of brain science instead of the conventional comparative test. There are two differences between each verification method. First, the former treats the patient as a group and the latter as an individual. Second, the former evaluates individual brain activity before and after practice, and the latter evaluates its changes over time. The former is most suitable for verifying the effect of the HT program for groups, and the latter is optimal for verifying the effect of functional horticultural tasks for individuals. In the future, it will be necessary to develop so that for the different types of functional horticultural tasks, multi-level complexity and difficulty can be set. This may promote personalized medicine for HT according to the severity and personality traits of the patient's disease.

A personality trait that controls the height of the patient's SE was added to the HT system model, and system dynamics were applied. It is a breakthrough method for quantifying the patient's personality traits and functional horticultural tasks, and their relationships over time. The horticultural therapist can reasonably set the type, difficulty, and complexity of the functional horticultural task according to the personality traits of the individual patient. The HT dynamics model constructed in this section is based on the premise that personality traits affect SE in one direction, but they may interact with each other. In the future, it will be necessary to clarify whether the relationship between SE and personality traits is unidirectional or bidirectional, and if the latter, modify the dynamics model so that they have a loop structure.

Patients' high SE and personality traits change daily with age and illness. By applying the PDCA cycle to HT, I proposed a treatment method that provides optimal functional horticultural tasks for the changing health status of patients. The new treatment was named PDCA cycle treatment. In order to circulate the PDCA cycle of HT over the long term, a dynamic framework was proposed in which treatment is systematically advanced using a dynamic model. This new treatment and framework should help promote personalized medicine in HT. It is necessary to gradually verify whether HT personalized medicine is effective in clinical practice and whether it can be integrated with WM personalized medicine.

5. 2. What is the essence of horticultural therapy?

Here, the essence of HT is mentioned and redefined so that its purpose and method can be uniquely understood.

The answer to the question of why plants are used as a medium of treatment is the conclusion of Chapter 2. The chapter showed that a vigorous behavioral cycle with high SE is important for patient functional recovery. Plants are triggers for stimulating patient perception and producing high SE. The triggering plant must meet the conditions of having physical characteristics that have a positive effect on the patient's mind and body, and affordances that induce active behavior. Horticultural therapists need to select plants that meet these requirements and work on functional horticultural tasks. Some patients are not positively affected by plants. Such patients should be referred to CAM using other therapeutic media such as music therapy, spa therapy, acupuncture, and moxibustion. Based on the above, HT was redefined as "a medical system that systematically improves the patient's mental state based on the rational decision-making of the horticultural therapist, using a functional horticultural task with a clarified mechanism of action." PDCA cycle treatment incorporating a dynamic model is useful for the planned treatment. The horticultural therapist must be an expert with horticultural and medical knowledge in order to improve the patient's mind and body reasonably and systematically.

In this study, I proposed personalized medicine as a new treatment method for HT in order to promote a medical system that integrates HT and WM for IM. Until now, HT has developed as an independent medical system for comprehensively improving the mind and body of patients. Group-based horticultural tasks and programs have been developed as treatments. HT personalized medicine is premised on integrating it with WM to provide long-term and systematic functional horticultural tasks according to the individual's disease, mental and physical condition, and speed of functional recovery. I defined HT as an independent medical system and HT integrated with WM as personalized medicine as horticultural medicine (HM).

The essence of HT and WM is the same, but there are three differences. First, it is up to the horticultural therapist to decide whether HT is free or paid, but WM is paid. Second, the treatment for HT is the HT program, and for WM is personalized medicine. The third is that HT is implemented independently as one type of CAM, but HM is implemented integrated with WM. It is important for horticultural therapists to understand the difference between HT and HM accurately and use them properly.

The value of activities using gardens and horticulture, which other CAMs do not have, may be that they can fully support social participation from the recovery of patients' mental and physical functions. Activities using gardens and horticulture are roughly divided into horticultural medicine (HM), horticultural therapy (HT), therapeutic horticulture (TH), vocational horticulture (VH), and social horticulture (SH). Figure 23 shows the purpose of activities using these gardens and horticulture, and the scope and method of treatment.

The therapeutic purpose of WM and HT is to promote the active behavior of patients. Its therapeutic range is to induce high SE and brain plasticity for functional recovery. WM uses personalized medicine and HT uses group-based medicine. TH, VH, and SH are usually aimed at training and social participation. They do not require a horticultural therapist and are achieved by participating in an already established HT program. The scope of treatment for TH, VH, and SH can be said to be physical activity, vocational training, and improvement of quality of life, respectively. The best treatment to achieve each treatment goal is to participate in HT programs, agricultural businesses, and gardens.

A series of activities using these gardens and horticulture can totally support the process from holistic improvement of the patient's physical and mental condition to social participation of the individual from the hospital. In fact, in Japan, there is growing interest in businesses such as temporarily engaging in agriculture to support the reintegration of people who have become depressed due to occupational stress. It is important for experts in each activity to support the step-by-step improvement of functions so that individuals can lead to the step of becoming independent and participating in society. If such a social system is established, problems such as the aging and declining agricultural population may be solved.

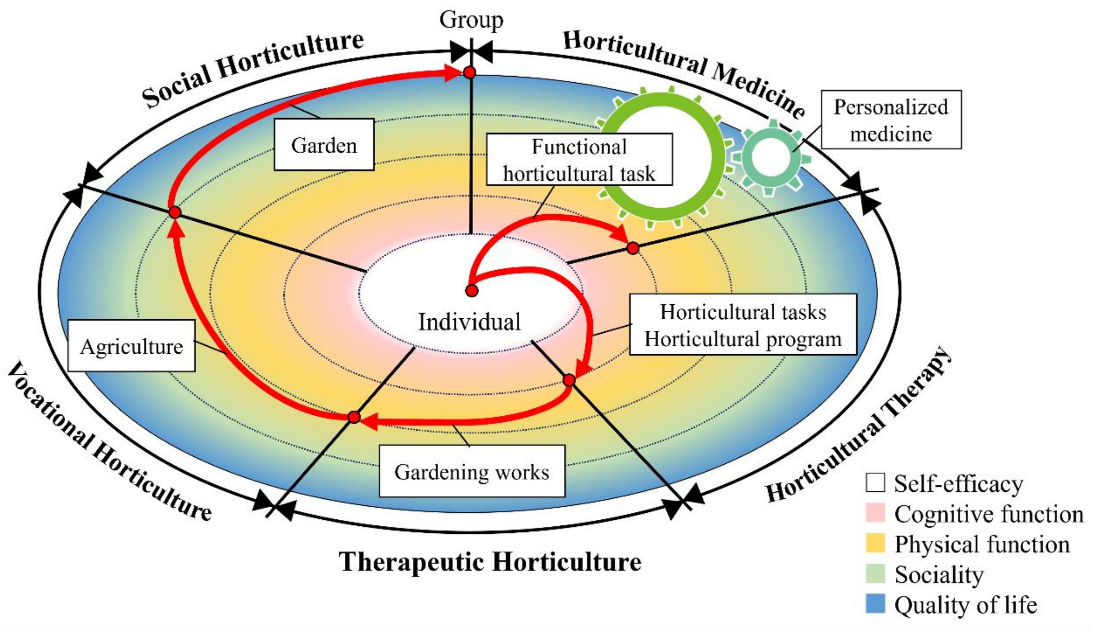

Figure 23. The purpose and scope of activities that use horticulture as a medium. The circle indicates the patient's health. From the center to the outside, the individual's self-efficacy, cognition, physical function, sociality, and quality of life were shown. They were identified as white, pink, yellow, green, and blue. The outside of this circle represents the patient's external environment. For example, it refers to society and other businesses, which are represented by the word “Group.” Horticultural medicine, horticultural therapy, therapeutic horticulture, vocational horticulture, and social horticulture are all located outside the circle because they are external environments. The range of patient health targeted by these activities is indicated by double-headed arrows. The red arrows pointing outward from the center indicate the purpose and scope of each type of horticultural activity. The red arrow indicates the type of task used in each activity. The yellow-green gears shown in the circle represent horticultural medicine, and the light blue gears represent personalized medicine. Since each treatment is specified, it is expressed by cogwheel.

References

[1] American Horticultural Therapy Association: Horticultural Therapy-History and Practice. https://www.ahta.org/about-horticultural-therapy (Accessed in December 2021)

[2] M. Toyoda, Horticultural therapy in Japan-History, Education, Character, Assessment, 創藝學報 JAD (2) (2012) 51-65.

[3] American Horticultural Therapy Association: Definition and Positions. https://ahta.memberclicks.net/assets/docs/final_ht_position_paper_updated_409.pdf (Accessed in December 2021)

[4] K. Son, S. Jung, A. Lee, S. Park, The theoretical model and universal definition of horticultural therapy, XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): XII 1121, 2014, pp. 79-88.

[5] American Horticultural Therapy Association: AHTA's Definition of a Horticultural Therapist. https://www.ahta.org/assets/docs/ht%20definition%202015%20rev.pdf (Accessed in November 2021)

[6] M.T. Gonzalez, T. Hartig, G.G. Patil, E.W. Martinsen, M. Kirkevold, Therapeutic horticulture in clinical depression: a prospective study, Research and Theory for Nursing Practice 23(4) (2009) 312-328.

[7] M.C. Kam, A.M. Siu, Evaluation of a horticultural activity programme for persons with psychiatric illness, Hong Kong journal of occupational therapy 20(2) (2010) 80-86.

[8] Y.-A. Oh, S.-A. Park, B.-E. Ahn, Assessment of the psychopathological effects of a horticultural therapy program in patients with schizophrenia, Complementary therapies in medicine 36 (2018) 54-58.

[9] S. Lu, Y. Zhao, J. Liu, F. Xu, Z. Wang, Effectiveness of Horticultural Therapy in People with Schizophrenia: A Systematic Review and Meta-Analysis, Int. J. Env. Res. Public Health 18(3) (2021) 964.

[10] S.E. Jarrott, H.R. Kwack, D. Relf, An observational assessment of a dementia-specific horticultural therapy program, HortTechnology 12(3) (2002) 403-410.

[11] S.E. Jarrott, C.M. Gigliotti, Comparing responses to horticultural-based and traditional activities in dementia care programs, American Journal of Alzheimer's Disease & Other Dementias® 25(8) (2010) 657-665.

[12] Y. Zhao, Y. Liu, Z. Wang, Effectiveness of horticultural therapy in people with dementia: A quantitative systematic review, J. Clin. Nursing (2020).

[13] M. Yasukawa, Horticultural therapy horticultural therapy for the cognitive functioning of elderly people elderly people with dementia, International Handbook of Occupational Therapy Interventions, Springer2009, pp. 431-444.

[14] H. Kamioka, K. Tsutani, M. Yamada, H. Park, H. Okuizumi, T. Honda, S. Okada, S.-J. Park, J. Kitayuguchi, T. Abe, Effectiveness of horticultural therapy: a systematic review of randomized controlled trials, Complementary therapies in medicine 22(5) (2014) 930-943.
[15] M. Toyoda, Y. Yokota, The effects of gardening activities on prefrontal area measured with near-infrared spectroscopy (NIRS), XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): XII 1121, 2014, pp. 33-38.
[16] A.A. Conti, Historical evolution of the concept of health in Western medicine, Acta Biomed 89(3) (2018) 352-354.
[17] C. Nardini, V. Osmani, P.G. Cormio, A. Frosini, M. Turrini, C. Lionis, T. Neumuth, W. Ballensiefen, E. Borgonovi, G. D'Errico, The evolution of personalized healthcare and the pivotal role of European regions in its implementation, Per Med 18(3) (2021) 283-294.
[18] G.R. Gameiro, V. Sinkunas, G.R. Liguori, J.O.C. Auler-Júnior, Precision Medicine: Changing the way we think about healthcare, Clinics (Sao Paulo) 73 (2018) e723.
[19] B. Djulbegovic, G.H. Guyatt, Progress in evidence-based medicine: a quarter century on, Lancet 390(10092) (2017) 415-423.
[20] D.L. Sackett, W.M. Rosenberg, J.A. Gray, R.B. Haynes, W.S. Richardson, Evidence based medicine: what it is and what it isn't, Bmj 312(7023) (1996) 71-2.
[21] L.H. Goetz, N.J. Schork, Personalized medicine: motivation, challenges, and progress, Fertil Steril 109(6) (2018) 952-963.
[22] I.S. Chan, G.S. Ginsburg, Personalized medicine: progress and promise, Annual review of genomics and human genetics 12 (2011) 217-244.
[23] S. Murata, M. Takegami, D. Onozuka, Y. Nakaoku, A. Hagihara, K. Nishimura, Incidence and Mortality of Dementia-Related Missing and Their Associated Factors: An Ecological Study in Japan, J Epidemiol 31(6) (2021) 361-368.
[24] I. Tsuji, Epidemiologic Research on Healthy Life Expectancy and Proposal for Its Extension: A Revised English Version of Japanese in the Journal of the Japan Medical Association 2019;148(9):1781-4, Jma j 3(3) (2020) 149-153.
[25] B.W. Ward, J.S. Schiller, R.A. Goodman, Peer reviewed: multiple chronic conditions among us adults: a 2012 update, Preventing chronic disease 11 (2014).
[26] B.W. Ward, J.S. Schiller, Prevalence of multiple chronic conditions among US adults: estimates from the National Health Interview Survey, 2010, Prev Chronic Dis 10 (2013) E65.
[27] P.Y. Collins, V. Patel, S.S. Joestl, D. March, T.R. Insel, A.S. Daar, I.A. Bordin, E.J. Costello, M. Durkin, C. Fairburn, Grand challenges in global mental health, Nature 475(7354) (2011) 27-30.
[28] S. Poongothai, R.M. Anjana, R. Pradeepa, A. Ganesan, R. Unnikrishnan, M. Rema, V.

Mohan, Association of depression with complications of type 2 diabetes-The Chennai Urban Rural Epidemiology Study (CURES-102), Journal of Association of Physicians of India 59 (2011) 640-644.
[29] M.R. Carnethon, M.L. Biggs, J.I. Barzilay, N.L. Smith, V. Vaccarino, A.G. Bertoni, A. Arnold, D. Siscovick, Longitudinal association between depressive symptoms and incident type 2 diabetes mellitus in older adults: the cardiovascular health study, Archives of internal medicine 167(8) (2007) 802-807.
[30] W.J. Katon, M. Von Korff, E.H. Lin, G. Simon, E. Ludman, J. Russo, P. Ciechanowski, E. Walker, T. Bush, The pathways study: A randomized trial of collaborative care in patients with diabetesand depression, Archives of general psychiatry 61(10) (2004) 1042-1049.
[31] W.J. Katon, E.H. Lin, M. Von Korff, P. Ciechanowski, E.J. Ludman, B. Young, D. Peterson, C.M. Rutter, M. McGregor, D. McCulloch, Collaborative care for patients with depression and chronic illnesses, New Engl. J. Med. 363(27) (2010) 2611-2620.
[32] D. Prabhakaran, S. Anand, D.A. Watkins, T.A. Gaziano, Y. Wu, J.-C. Mbanya, R. Nugent, Cardiovascular, respiratory, and related disorders: key messages and essential interventions to address their burden in low-and middle-income Countries, rd, Prabhakaran D, Anand S, Gaziano TA, Mbanya JC, Wu Y et al., editors. Cardiovascular, Respiratory, and Related Disorders (2017).
[33] C.F. Ski, M. Jelinek, A.C. Jackson, B.M. Murphy, D.R. Thompson, Psychosocial interventions for patients with coronary heart disease and depression: A systematic review and meta-analysis, European Journal of Cardiovascular Nursing 15(5) (2016) 305-316.
[34] P.M. Barnes, B. Bloom, R.L. Nahin, Complementary and alternative medicine use among adults and children; United States, 2007, (2008).
[35] F. de Almeida Andrade, C.F. Schlechta Portella, Research methods in complementary and alternative medicine: an integrative review, J Integr Med 16(1) (2018) 6-13.
[36] E. Ernst, Integrated medicine, J Intern Med 271(1) (2012) 25-8.
[37] H. MacPherson, D. Peters, C. Zollman, Closing the evidence gap in integrative medicine, Bmj 339 (2009) b3335.
[38] V. Maizes, D. Rakel, C. Niemiec, Integrative medicine and patient-centered care, Explore (NY) 5(5) (2009) 277-89.
[39] M.L. Dossett, E.M. Cohen, J. Cohen, Integrative Medicine for Gastrointestinal Disease, Prim Care 44(2) (2017) 265-280.
[40] G. Deng, Integrative Medicine Therapies for Pain Management in Cancer Patients, Cancer J. 25(5) (2019) 343-348.
[41] S. Zhu, H. Wan, Z. Lu, H. Wu, Q. Zhang, X. Qian, C. Ye, Treatment effect of antipsychotics in combination with horticultural therapy on patients with schizophrenia: a randomized,

double-blind, placebo-controlled study, Shanghai archives of psychiatry 28(4) (2016) 195.
[42] F. Heylighen, Basic Concepts of the Systems Approach (Accessed in January 2021)
[43] P.D. Relf, Theoretical models for research and program development in agriculture and health care: avoiding random acts of research, Farming for health, Springer2006, pp. 1-20.
[44] Bandura A (1977) Self-efficacy: The exercise of control. New York: W. H. Freeman.
[45] P. Sheeran, A. Maki, E. Montanaro, A. Avishai-Yitshak, A. Bryan, W.M. Klein, E. Miles, A.J. Rothman, The impact of changing attitudes, norms, and self-efficacy on health-related intentions and behavior: A meta-analysis, Health Psychol. 35(11) (2016) 1178-1188.
[46] A.M. Selzler, R. Habash, L. Robson, E. Lenton, R. Goldstein, D. Brooks, Self-efficacy and health-related quality of life in chronic obstructive pulmonary disease: A meta-analysis, Patient Educ Couns 103(4) (2020) 682-692.
[47] H. Farley, Promoting self-efficacy in patients with chronic disease beyond traditional education: A literature review, Nurs Open 7(1) (2020) 30-41.
[48] V. Brenninkmeijer, S.E. Lagerveld, R.W. Blonk, W.B. Schaufeli, L.D. Wijngaards-de Meij, Predicting the effectiveness of work-focused CBT for common mental disorders: the influence of baseline self-efficacy, depression and anxiety, J. Occup. Rehabil. 29(1) (2019) 31-41.
[49] J.B. Tonga, D.E. Eilertsen, I.K.L. Solem, E.A. Arnevik, M.S. Korsnes, I.D. Ulstein, Effect of Self-Efficacy on Quality of Life in People With Mild Cognitive Impairment and Mild Dementia: The Mediating Roles of Depression and Anxiety, Am J Alzheimers Dis Other Demen 35 (2020) 1533317519885264.
[50] J.J. Gibson, The ecological approach to visual perception: classic edition, Psychology Press (2014).
[51] P. Garrido-Vásquez, A. Schubö, Modulation of visual attention by object affordance, Front Psychol 5 (2014) 59.
[52] J.M. Phillips, A.M. Stalter, Systems Thinking for Managing COVID-19 in Health Care Systems: Seven Key Messages, J Contin Educ Nurs 51(9) (2020) 402-411.
[53] E. Iacovidou, J.N. Hahladakis, P. Purnell, A systems thinking approach to understanding the challenges of achieving the circular economy, Environ Sci Pollut Res Int 28(19) (2021) 24785-24806.
[54] S. Chughtai, K. Blanchet, Systems thinking in public health: a bibliographic contribution to a meta-narrative review, Health Policy Plan 32(4) (2017) 585-594.
[55] R.F. Titcombe-Parekh, J. Chen, N. Rahman, N. Kouri, M. Qian, M. Li, R.A. Bryant, C.R. Marmar, A.D. Brown, Neural circuitry changes associated with increasing self-efficacy in Posttraumatic Stress Disorder, Journal of psychiatric research 104 (2018) 58-64.
[56] T.H. Murphy, D. Corbett, Plasticity during stroke recovery: from synapse to behaviour, Nat. Rev. Neurosci. 10(12) (2009) 861-72.

[57] S.N. Burke, C.A. Barnes, Neural plasticity in the ageing brain, Nat. Rev. Neurosci. 7(1) (2006) 30-40.
[58] H.W. Mahncke, A. Bronstone, M.M. Merzenich, Brain plasticity and functional losses in the aged: scientific bases for a novel intervention, Prog. Brain Res. 157 (2006) 81-109.
[59] G. Chen, W.J. Casper, J.M. Cortina, The roles of self-efficacy and task complexity in the relationships among cognitive ability, conscientiousness, and work-related performance: A meta-analytic examination, Hum. Perform. 14(3) (2001) 209-230.
[60] C. Holmes, C. Ballard, Aromatherapy in dementia, Advances in psychiatric treatment 10(4) (2004) 296-300.
[61] H. Jo, S. Rodiek, E. Fujii, Y. Miyazaki, B.-J. Park, S.-W. Ann, Physiological and psychological response to floral scent, HortScience 48(1) (2013) 82-88.
[62] D. Duro, P. Cerveira, B. Santiago, M.J. Cunha, J.M. Pedroso de Lima, M.A. Botelho, I. Santana, Clock drawing test in mild cognitive impairment: Correlation with cerebral perfusion in single-photon emission computed tomography, Neuropsychology 33(5) (2019) 617-632.
[63] N. Atherton, C. Bridle, D. Brown, H. Collins, S. Dosanjh, F. Griffiths, S. Hennings, K. Khan, R. Lall, S. Lyle, R. McShane, D. Mistry, V. Nichols, S. Petrou, B. Sheehan, A.M. Slowther, M. Thorogood, E. Withers, P. Zeh, S.E. Lamb, Dementia and Physical Activity (DAPA) - an exercise intervention to improve cognition in people with mild to moderate dementia: study protocol for a randomized controlled trial, Trials 17 (2016) 165.
[64] A. Baird, W.F. Thompson, The Impact of Music on the Self in Dementia, J Alzheimers Dis 61(3) (2018) 827-841.
[65] L.J. Dominguez, M. Barbagallo, M. Muñoz-Garcia, J. Godos, M.A. Martinez-Gonzalez, Dietary Patterns and Cognitive Decline: key features for prevention, Curr. Pharm. Des. 25(22) (2019) 2428-2442.
[66] K. Kouloutbani, K. Karteroliotis, A. Politis, [The effect of physical activity on dementia], Psychiatriki 30(2) (2019) 142-155.
[67] J. Kowalska, J. Mazurek, N. Kubasik, J. Rymaszewska, Effectiveness of physiotherapy in elderly patients with dementia: a prospective, comparative analysis, Disabil Rehabil 41(7) (2019) 815-819.
[68] A. Soler, G. Amer, A. Leiva, J. Ripoll, M.A. Llorente, A. Leiva, J.M. Taltavull, R. Molina, J. Llobera, Continuation versus discontinuation of treatment for severe dementia: randomized, pragmatic, open-label, clinical trial to evaluate the efficacy of continuing drug treatment in patients with severe dementia (STOP-DEM), BMC Geriatr. 19(1) (2019) 101.
[69] N. Levy-Cooperman, A.M. Burhan, S. Rafi-Tari, M. Kusano, J. Ramirez, C. Caldwell, S.E. Black, Frontal lobe hypoperfusion and depressive symptoms in Alzheimer disease, J

Psychiatry Neurosci 33(3) (2008) 218-26.
[70] R.J. Melrose, M.L. Ettenhofer, D. Harwood, N. Achamallah, O. Campa, M. Mandelkern, D.L. Sultzer, Cerebral metabolism, cognition, and functional abilities in Alzheimer disease, J Geriatr Psychiatry Neurol 24(3) (2011) 127-34.
[71] J. Cohen-Mansfield, M.S. Marx, M. Dakheel-Ali, K. Thein, The use and utility of specific nonpharmacological interventions for behavioral symptoms in dementia: an exploratory study, Am J Geriatr Psychiatry 23(2) (2015) 160-70.
[72] Y. Morita, F. Ebara, Y. Morita, E. Horikawa, Increased activity in the right prefrontal cortex measured using near-infrared spectroscopy during a flower arrangement task, International journal of psychiatry in clinical practice 22(1) (2018) 34-39.
[73] M.D.C. Pérez-Fuentes, M.D.M. Molero Jurado, J.J. Gázquez Linares, N.F. Oropesa Ruiz, M.D.M. Simón Márquez, M. Saracostti, Self-Expressive Creativity in the Adolescent Digital Domain: Personality, Self-Esteem, and Emotions, Int J Environ Res Public Health 16(22) (2019).
[74] T. Nguyen, M. Kim, J. Gwak, J.J. Lee, K.Y. Choi, K.H. Lee, J.G. Kim, Investigation of brain functional connectivity in patients with mild cognitive impairment: A functional near-infrared spectroscopy (fNIRS) study, J Biophotonics 12(9) (2019) e201800298.
[75] V. Murugaraja, V. Shivakumar, P.T. Sivakumar, P. Sinha, G. Venkatasubramanian, Clinical utility and tolerability of transcranial direct current stimulation in mild cognitive impairment, Asian J Psychiatr 30 (2017) 135-140.
[76] W.C. Ung, K.H. Yap, E.G.M. Ebenezer, P.S. Chin, N. Nordin, S.C. Chan, H.L. Yip, C.K. Lu, M. Kiguchi, T.B. Tang, Assessing Neural Compensation With Visuospatial Working Memory Load Using Near-Infrared Imaging, IEEE Trans Neural Syst Rehabil Eng 28(1) (2020) 13-22.
[77] M.K. Yeung, A.S. Chan, Functional near-infrared spectroscopy reveals decreased resting oxygenation levels and task-related oxygenation changes in mild cognitive impairment and dementia: A systematic review, J Psychiatr Res 124 (2020) 58-76.
[78] B. Dubois, H.H. Feldman, C. Jacova, J.L. Cummings, S.T. DeKosky, P. Barberger-Gateau, A. Delacourte, G. Frisoni, N.C. Fox, D. Galasko, S. Gauthier, H. Hampel, G.A. Jicha, K. Meguro, J. O'Brien, F. Pasquier, P. Robert, M. Rossor, S. Salloway, M. Sarazin, L.C. de Souza, Y. Stern, P.J. Visser, P. Scheltens, Revising the definition of Alzheimer's disease: a new lexicon, The Lancet Neurology 9(11) (2010) 1118-1127.
[79] B.V. Zlokovic, Neurovascular pathways to neurodegeneration in Alzheimer's disease and other disorders, Nat. Rev. Neurosci. 12(12) (2011) 723-38.
[80] C.R. Jack, Jr., D.A. Bennett, K. Blennow, M.C. Carrillo, B. Dunn, S.B. Haeberlein, D.M. Holtzman, W. Jagust, F. Jessen, J. Karlawish, E. Liu, J.L. Molinuevo, T. Montine, C. Phelps,

K.P. Rankin, C.C. Rowe, P. Scheltens, E. Siemers, H.M. Snyder, R. Sperling, Contributors, NIA-AA Research Framework: Toward a biological definition of Alzheimer's disease, Alzheimers Dement 14(4) (2018) 535-562.

[81] H. Zhang, Y. Wang, D. Lyu, Y. Li, W. Li, Q. Wang, Y. Li, Q. Qin, X. Wang, M. Gong, H. Jiao, W. Liu, J. Jia, Cerebral blood flow in mild cognitive impairment and Alzheimer's disease: A systematic review and meta-analysis, Ageing Res Rev 71 (2021) 101450.

[82] S.E. Berman, L.A. Rivera-Rivera, L.R. Clark, A.M. Racine, J.G. Keevil, L.C. Bratzke, C.M. Carlsson, B.B. Bendlin, H.A. Rowley, K. Blennow, H. Zetterberg, S. Asthana, P. Turski, S.C. Johnson, O. Wieben, Intracranial Arterial 4D-Flow is Associated with Metrics of Brain Health and Alzheimer's Disease, Alzheimers Dement (Amst) 1(4) (2015) 420-428.

[83] M.A. Daulatzai, Cerebral hypoperfusion and glucose hypometabolism: Key pathophysiological modulators promote neurodegeneration, cognitive impairment, and Alzheimer's disease, J. Neurosci. Res. 95(4) (2017) 943-972.

[84] M. Encinas, R. De Juan, A. Marcos, P. Gil, A. Barabash, C. Fernandez, C. De Ugarte, J.A. Cabranes, Regional cerebral blood flow assessed with 99mTc-ECD SPET as a marker of progression of mild cognitive impairment to Alzheimer's disease, Eur J Nucl Med Mol Imaging 30(11) (2003) 1473-80.

[85] L.L. Chao, S.T. Buckley, J. Kornak, N. Schuff, C. Madison, K. Yaffe, B.L. Miller, J.H. Kramer, M.W. Weiner, ASL perfusion MRI predicts cognitive decline and conversion from MCI to dementia, Alzheimer disease and associated disorders 24(1) (2010) 19.

[86] L.R. Clark, S.E. Berman, L.A. Rivera-Rivera, S.M. Hoscheidt, B.F. Darst, C.D. Engelman, H.A. Rowley, C.M. Carlsson, S. Asthana, P. Turski, O. Wieben, S.C. Johnson, Macrovascular and microvascular cerebral blood flow in adults at risk for Alzheimer's disease, Alzheimers Dement (Amst) 7 (2017) 48-55.

[87] N.P. Friedman, T.W. Robbins, The role of prefrontal cortex in cognitive control and executive function, Neuropsychopharmacology (2021).

[88] H. Takeuchi, Y. Taki, R. Nouchi, H. Hashizume, A. Sekiguchi, Y. Kotozaki, S. Nakagawa, C.M. Miyauchi, Y. Sassa, R. Kawashima, Effects of working memory training on functional connectivity and cerebral blood flow during rest, Cortex 49(8) (2013) 2106-25.

[89] S.B. Chapman, S. Aslan, J.S. Spence, J.J. Hart Jr, E.K. Bartz, N. Didehbani, M.W. Keebler, C.M. Gardner, J.F. Strain, L.F. DeFina, Neural mechanisms of brain plasticity with complex cognitive training in healthy seniors, Cereb. Cortex 25(2) (2015) 396-405.

[90] H. Mochizuki-Kawai, Y. Yamakawa, S. Mochizuki, S. Anzai, M. Arai, Structured floral arrangement programme for improving visuospatial working memory in schizophrenia, Neuropsychological rehabilitation 20(4) (2010) 624-636.

[91] R. Rosli, M.P. Tan, W.K. Gray, P. Subramanian, A.-V. Chin, Cognitive assessment tools

in Asia: a systematic review, International psychogeriatrics 28(2) (2016) 189-210.
[92] P.A. Thomann, P. Toro, V. Dos Santos, M. Essig, J. Schröder, Clock drawing performance and brain morphology in mild cognitive impairment and Alzheimer’s disease, Brain and cognition 67(1) (2008) 88-93.
[93] J.J.d. Paula, D.M.d. Miranda, E.N.d. Moraes, L.F. Malloy-Diniz, Mapping the clockworks: what does the Clock Drawing Test assess in normal and pathological aging?, Arquivos de Neuro-Psiquiatria 71 (2013) 763-768.
[94] M.D. Nunez, R. Srinivasan, J. Vandekerckhove, Individual differences in attention influence perceptual decision making, Frontiers in psychology 6 (2015) 18.
[95] P.M. Greenwood, R. Parasuraman, G.E. Alexander, Controlling the focus of spatial attention during visual search: effects of advanced aging and Alzheimer disease, Neuropsychology 11(1) (1997) 3.
[96] C.Y. Santos, P.J. Snyder, W.-C. Wu, M. Zhang, A. Echeverria, J. Alber, Pathophysiologic relationship between Alzheimer's disease, cerebrovascular disease, and cardiovascular risk: a review and synthesis, Alzheimer's & Dementia: Diagnosis, Assessment & Disease Monitoring 7 (2017) 69-87.
[97] E.M. van der Beek, P.J. Kamphuis, The potential role of nutritional components in the management of Alzheimer's Disease, Eur. J. Pharmacol. 585(1) (2008) 197-207.
[98] P.J. Kamphuis, P. Scheltens, Can nutrients prevent or delay onset of Alzheimer's disease?, J. Alzheimer's Dis. 20(3) (2010) 765-775.
[99] C. Lange-Asschenfeldt, G. Kojda, Alzheimer’s disease, cerebrovascular dysfunction and the benefits of exercise: from vessels to neurons, Experimental gerontology 43(6) (2008) 499-504.
[100] T. Nishijima, I. Torres-Aleman, H. Soya, Exercise and cerebrovascular plasticity, Prog. Brain Res. 225 (2016) 243-268.
[101] P. Burbaud, P. Degreze, P. Lafon, J.-M. Franconi, B. Bouligand, B. Bioulac, J. Caille, M. Allard, Lateralization of prefrontal activation during internal mental calculation: a functional magnetic resonance imaging study, J. Neurophysiol. 74(5) (1995) 2194-2200.
[102] R.H. Grabner, D. Ansari, G. Reishofer, E. Stern, F. Ebner, C. Neuper, Individual differences in mathematical competence predict parietal brain activation during mental calculation, NeuroImage 38(2) (2007) 346-356.
[103] W.J. TIPPETT, S.E. BLACK, Regional cerebral blood flow correlates of visuospatial tasks in Alzheimer's disease, Journal of the International Neuropsychological Society: JINS 14(6) (2008) 1034.
[104] J.M. Chein, J.A. Fiez, Dissociation of verbal working memory system components using a delayed serial recall task, Cereb. Cortex 11(11) (2001) 1003-1014.

[105] J.D. Gabrieli, R.A. Poldrack, J.E. Desmond, The role of left prefrontal cortex in language and memory, Proc Natl Acad Sci U S A 95(3) (1998) 906-13.
[106] E. Weiss, C. Siedentopf, A. Hofer, E. Deisenhammer, M. Hoptman, C. Kremser, S. Golaszewski, S. Felber, W. Fleischhacker, M. Delazer, Brain Activation Pattern During a Verbal Fluency Test in Healthy Male and Female Volunteers: A Functional Magnetic Resonance Imaging Study, Neurosci. Lett. 352(3) (2003) 191-194.
[107] T.S. Braver, S.R. Bongiolatti, The role of frontopolar cortex in subgoal processing during working memory, NeuroImage 15(3) (2002) 523-536.
[108] C. Habak, M.L. Seghier, J. Brûlé, M.A. Fahim, O. Monchi, Age Affects How Task Difficulty and Complexity Modulate Perceptual Decision-Making, Frontiers in aging neuroscience 11 (2019) 28.
[109] J. Gläscher, R. Adolphs, H. Damasio, A. Bechara, D. Rudrauf, M. Calamia, L.K. Paul, D. Tranel, Lesion mapping of cognitive control and value-based decision making in the prefrontal cortex, Proceedings of the National Academy of Sciences 109(36) (2012) 14681-14686.
[110] F. Dolcos, K.S. LaBar, R. Cabeza, Dissociable effects of arousal and valence on prefrontal activity indexing emotional evaluation and subsequent memory: an event-related fMRI study, NeuroImage 23 (2004) 64-74.
[111] D. Schiller, J.W. Kanen, J.E. LeDoux, M.-H. Monfils, E.A. Phelps, Extinction during reconsolidation of threat memory diminishes prefrontal cortex involvement, Proceedings of the National Academy of Sciences 110(50) (2013) 20040-20045.
[112] N. Levy-Cooperman, A.M. Burhan, S. Rafi-Tari, M. Kusano, J. Ramirez, C. Caldwell, S.E. Black, Frontal lobe hypoperfusion and depressive symptoms in Alzheimer disease, Journal of psychiatry & neuroscience: JPN 33(3) (2008) 218.
[113] I. Sotiropoulos, C. Catania, L.G. Pinto, R. Silva, G.E. Pollerberg, A. Takashima, N. Sousa, O.F. Almeida, Stress acts cumulatively to precipitate Alzheimer's disease-like tau pathology and cognitive deficits, J. Neurosci. 31(21) (2011) 7840-7847.
[114] C. Catania, I. Sotiropoulos, R. Silva, C. Onofri, K. Breen, N. Sousa, O. Almeida, The amyloidogenic potential and behavioral correlates of stress, Mol. Psychiatry 14(1) (2009) 95-105.
[115] H.Y. Chan, R.C.-M. Ho, R. Mahendran, K.S. Ng, W. Wai-San Tam, I. Rawtaer, C.H. Tan, A. Larbi, L. Feng, A. Sia, Effects of horticultural therapy on elderly'health: protocol of a randomized controlled trial, BMC Geriatr. 17(1) (2017) 1-10.
[116] J. Hall, G. Mitchell, C. Webber, K. Johnson, Effect of horticultural therapy on wellbeing among dementia day care programme participants: A mixed-methods study (Innovative Practice), Dementia 17(5) (2018) 611-620.

[117] S.A. Gale, D. Acar, K.R. Daffner, Dementia, Am. J. Med. 131(10) (2018) 1161-1169.
[118] R. Bullock, G. Hammond, Realistic expectations: the management of severe Alzheimer disease, Alzheimer Dis Assoc Disord 17 Suppl 3 (2003) S80-5.
[119] S.G. Potkin, The ABC of Alzheimer's disease: ADL and improving day-to-day functioning of patients, Int Psychogeriatr 14 Suppl 1 (2002) 7-26.
[120] M.T. Gonzalez, M. Kirkevold, Benefits of sensory garden and horticultural activities in dementia care: a modified scoping review, J Clin Nurs 23(19-20) (2014) 2698-715.
[121] Y. Yang, R.Y.C. Kwan, H.M. Zhai, Y. Xiong, T. Zhao, K.L. Fang, H.Q. Zhang, Effect of horticultural therapy on apathy in nursing home residents with dementia: a pilot randomized controlled trial, Aging Ment Health (2021) 1-9.
[122] R.B. Curtin, B.A. Walters, D. Schatell, P. Pennell, M. Wise, K. Klicko, Self-efficacy and self-management behaviors in patients with chronic kidney disease, Adv Chronic Kidney Dis 15(2) (2008) 191-205.
[123] T.A. Judge, C.L. Jackson, J.C. Shaw, B.A. Scott, B.L. Rich, Self-efficacy and work-related performance: the integral role of individual differences, J Appl Psychol 92(1) (2007) 107-27.
[124] J. Jones, D. Hunter, Consensus methods for medical and health services research, Bmj 311(7001) (1995) 376-80.
[125] P. Waterson, A critical review of the systems approach within patient safety research, Ergonomics 52(10) (2009) 1185-95.
[126] J.S. Torday, W.B. Miller, Jr., A systems approach to physiologic evolution: From micelles to consciousness, J Cell Physiol 233(1) (2018) 162-167.
[127] J.T. Yurkovich, Q. Tian, N.D. Price, L. Hood, A systems approach to clinical oncology uses deep phenotyping to deliver personalized care, Nat Rev Clin Oncol 17(3) (2020) 183-194.
[128] D. Stevens, D.I. Anderson, N.J. O'Dwyer, A.M. Williams, Does self-efficacy mediate transfer effects in the learning of easy and difficult motor skills?, Consciousness and Cognition 21(3) (2012) 1122-1128.
[129] D.J. Campbell, Task complexity: A review and analysis, Academy of management review 13(1) (1988) 40-52.
[130] H. Makizako, K. Tsutsumimoto, T. Doi, R. Hotta, S. Nakakubo, T. Liu-Ambrose, H. Shimada, Effects of exercise and horticultural intervention on the brain and mental health in older adults with depressive symptoms and memory problems: study protocol for a randomized controlled trial [UMIN000018547], Trials 16 (2015) 499.
[131] H. Makizako, K. Tsutsumimoto, T. Doi, K. Makino, S. Nakakubo, T. Liu-Ambrose, H. Shimada, Exercise and Horticultural Programs for Older Adults with Depressive Symptoms and Memory Problems: A Randomized Controlled Trial, J Clin Med 9(1) (2019).

[132] T. Hanawa, K. Momo, [PDCA Cycle for the Development of Clinical Formulation Thinking in Actual Example], Yakugaku Zasshi 139(10) (2019) 1267-1268.
[133] Y. Chen, J. Zheng, D. Wu, Y. Zhang, Y. Lin, Application of the PDCA cycle for standardized nursing management in a COVID-19 intensive care unit, Ann Palliat Med 9(3) (2020) 1198-1205.
[134] S. Mita, M. Hosokawa, T. Hayashi, Appropriate horticultural therapy task setting considering patient's self-efficacy and personality: modeling the therapist's perspective on elderly patients with dementia, XV International People Plant Symposium and II International Symposium on Horticultural Therapies: the Role of Horticulture in 1330, 2021, pp. 1-10.

Acknowledgements

I would like to express my sincere gratitude to those who supported my research life at Kindai University Graduate School.

I would like to express my sincere gratitude to my academic advisor, Professor Takahiro Hayashi. Professor Hayashi respected my desire to learn about horticultural therapy and gave me sincere guidance. He taught me the scientific knowledge, research techniques, writing techniques, and thinking methods needed to study horticultural therapy. It is a lifelong treasure to be able to know the fun of exploration through the guidance of Professor Hayashi. His words of encouragement gave me courage, no matter how difficult it was. And those words have always guided me towards hope. I would like to express my sincere gratitude to Professor Hayashi for giving me a lot of guidance.

I would like to express my sincere gratitude to Professor Munetaka Hosokawa for his guidance and words of encouragement. He taught me how to design lectures and practices as a university faculty member. He also provided constructive advice on horticultural therapy research from the perspective of plant physiology and genetics. Thank you from the bottom of my heart.

I would like to express my sincere gratitude to Professor Morio Iijima for his constructive advice in writing the thesis. He advised me on the techniques needed to present my research to the audience. I would like to express my sincere gratitude for his encouragement.

I would like to thank everyone at the nursing care facility "Owada no Sato" for their cooperation in writing the dissertation. I would like to thank Dr. Tomofumi Morita for giving me knowledge about dementia and providing an experimental environment. I would like to thank Ryusuke Kusaka for managing the health information of the participants and managing the schedule for this experiment. I would also like to thank Hiroaki Imanishi for helping participants and their families give informed consent and ensuring the safety of the experiment.

I am grateful to my friends who entertain me in my daily life. I am grateful to the people who have given me much advice and had discussions with me through my research activities and conference presentations. I am grateful to the juniors of the same research team. Discussions with them stimulated my curiosity and gave me new insights. The time spent with everyone was fun and irreplaceable.

Last but not least, I would like to express my sincere gratitude to my father and mother for supporting my daily research life. My parents gave me the time and environment to immerse myself in my research. They always encouraged me, cheered me on, and healed my heart. Thanks to that, I continued to challenge myself with intellectual curiosity and was able to lead a happy student life. I am proud of my wonderful parents. I am grateful to my grandparents for inspiring my interest in research. My grandparents have taught me about nature, animals, traditional techniques, and the fun of creating since I was a child. And my brothers watched over my challenges. I am deeply grateful to my parents, grandparents, and siblings for always giving me love and courage.