FROM RESEARCH TO PRACTICE: OPERATIONALISATION OF THE EIGHT PERCEIVED SENSORY DIMENSIONS INTO A HEALTH-PROMOTING DESIGN TOOL

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ABSTRACT

Current trends in urbanisation present challenges connected to human health. In the Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities, the European Union acknowledges the role nature can play in relation to these challenges. The World Health Organization (WHO) calls for green space interventions to address urban health issues such as mental health and furthermore emphasises the need for more information on designing efficient health-promoting urban green spaces. This paper considers how green spaces may be designed to promote human mental health. Previous research reports that certain nature quality types, Perceived Sensory Dimensions (PSDs), have positive impacts on mental health. This paper aims to describe operationalisation of the PSDs into an applicable design tool for practitioners, such as landscape architects and urban planners. The paper includes the application of the tool in the design of Health Forest Octovia® research and demonstration setting. This operationalisation resulted in a design tool with six steps: 1. Determine the aim of the PSD, 2. Determine the scale, 3. Identify context, 4. Identify existing rooms, 5. Identify and graduate existing PSDs, and 6. Start design phase. After establishing Health Forest Octovia®, a research study validated the health-promoting design. Further validation of the design tool, however, requires its application in other research-based design projects. The current study concludes that the 8 PSD health-promoting design tool could function as an evidence-based design tool for nature-based solutions and could enhance sustainable urbanisation by promoting the mental health of residents.

Keywords: *: Evidence-based design, health design, health promotion, landscape architecture, mental health, nature-based solutions, sustainable urban planning, urbanisation*

1. INTRODUCTION

Today, over 70 percent of Europe's population lives in cities, a figure that is expected to increase to over 80 per cent by 2050 (European Union, 2015). This urbanisation may present challenges related to, for example, human health, loss of natural capital, and climate change (European Union, 2015). The European Union (EU) recognises the important role nature can play relative to these challenges. The EU Research and Innovation policy agenda on Nature-Based Solutions and Re-Naturing Cities was published in 2015 with the aim of positioning the EU as a leading actor in "innovating cities with nature" (European Union, 2015, p. 28). The EU uses the term 'nature-based solutions' for various solutions inspired and supported by nature (European Union, 2015). 'Enhancing sustainable urbanization' is one area that the EU claims can be addressed by nature-based solutions, with nature-based solutions stimulating "economic growth as well as improving the environment, making cities more attractive, and enhancing human well-being" (European Union, 2015, p. 4). Admirable though the EU's ambitions may be, challenges remain. One challenge is to understand that not all green spaces promote human health (Marcus & Sachs, 2014). This is central to the concept of 'health design' within landscape architecture, which is defined as "the conscious design of green spaces and gardens so that they, in a certain way, support health processes and result in improved health outcomes" (Stigsdotter, 2015, p. 90). This is also noted by the World Health Organization (WHO) regional office for Europe, which states that "understanding how to design and deliver effective urban green space interventions is critical to ensuring that urban green space delivers on its reported positive health, social and environmental outcomes" (WHO, 2017, p. 6). Various projects have sought to develop green space indicators or assessment tools for public health (e.g. van den Bosch et al., 2015). These indicators and tools frequently focus on factors such as distance to and size of green spaces but fail to address the quality of green spaces and lack applicability in the actual design process.

It is likewise crucial for designers to understand what health is and how green spaces can support health. The WHO defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHO, 1948, p. 100). This is a holistic definition, though research indicates that green spaces can support health via different pathways, by indirectly encouraging physical activity (Lovell, 2016) and social activities (Maas, van Dillen, Verheij, & Groenewegen, 2009) as well as by directly improving mental health by offering mental restoration (Hartig, Evans, Jamner, Davis, & Gärling, 2003). Mental restoration refers to a process in which mental recovery is triggered by certain components of the environment (Kaplan, 1995). These components are most often found in natural environments, which are thereby referred to as 'restorative environments' (Kaplan, 1995).

1.1 Research Project on Nature Qualities that Support Mental Health

On the basis of a joint project, researchers from the University of Copenhagen and the Swedish University of Agricultural Sciences (SLU) argued that not all green spaces are capable of supporting human health (Grahn & Stigsdotter, 2010). The researchers claimed that quality of green spaces is crucial. The overall hypothesis was that "People perceive green spaces in terms of certain dimensions" and that "some dimensions are more important than others as regards restoring people from stress" (Grahn & Stigsdotter, 2010, p. 266). One significant research question addressed was whether people suffering from stress prefer different dimensions to people who are not stressed (Grahn & Stigsdotter, 2010). Nearly 1000 randomly selected informants in Sweden answered a questionnaire regarding their preferences for nature qualities and self-assessments of health. The data was analysed using factor analysis, and eight factors with regard to preferences for nature qualities were identified (Table 1). This was the third time these eight dimensions had been identified in research, but it was the first time it had been possible to correlate them with mental health (Grahn & Stigsdotter, 2010.). The factors were interpreted as Perceived Sensory Dimensions (PSDs). People in general prefer the PSD Serene, followed by Space, Nature, Rich in Species, Refuge, Culture, Prospect, and Social (Grahn & Stigsdotter, 2010.). The PSDs Refuge and Nature were most strongly associated with stress. However, the individual PSDs are seldom found in isolation, and the research project identified a combination of Refuge, Nature, and Rich in Species, with no presence of Social, as the most restorative environment for stressed individuals (Grahn & Stigsdotter, 2010).

Land owners, managers, and policymakers have shown considerable interest in the 8 PSDs but have complained that they are difficult to apply in practice. As a result, the University of Copenhagen initiated the Health Forest Octovia® project, a full-scale research and demonstration setting established within Denmark's largest arboretum. Health Forest Octovia® covers an area of approximately 2 hectares and is composed of eight different spatial settings, referred to as 'rooms'. Each room has been redesigned to accentuate one particular PSD. A 750-meter trail connects the eight rooms in a circular walk. After Health Forest Octovia® was established, a mixed-methods research project with a crossover design was conducted. The project results confirm that informants experience Health Forest Octovia® as mentally restorative, as measured by the Perceived Restorativeness Scale (PRS) (Stigsdotter, Corazon, Sidenius, Kristensen, & Grahn, 2017a). Health Forest Octovia® also proved more physiologically restorative than an office or a bus ride, as measured by Heart Rate Variability (HRV) and pulse (Stigsdotter et al., 2017a). The Profile of Mood Scale (POMS) psychological questionnaire also supported the positive impact of Health Forest Octovia® on informants' mood (Stigsdotter et al., 2017a). Informants furthermore ranked the rooms representing Serene, Rich in Species, Refuge, and Nature as the most restorative, thereby confirming the earlier research results (Stigsdotter, Corazon, Sidenius, Refshauge, & Grahn, 2017b). We interpret the results as a validation of Health Forest Octovia®'s design. In parallel with Health Forest Octovia®'s design process, we developed and applied a stepwise model for how the PSDs could be applied in practice. In this paper, the term 'operationalise' is defined as 'put into operation or use'. The paper aims to transparently describe the operationalisation and application of this stepwise model, which we believe can serve as a tool for designing health-promoting green spaces.

2. MATERIALS AND METHODS

As mentioned above, the 8 PSDs health-promoting design tool was developed during the design process of Health Forest Octovia®. Grounded in the need for evidence-based and transparent work processes, the team of designers and researchers documented the entire design process and all design decisions in great detail. Input from both practitioners and students was also considered when developing the six steps that constitute the PSDs health-promoting design tool.

2.1 Operationalisation of the Eight Perceived Sensory Dimensions into a Design Tool

The 8 PSDs are a result and interpretation of a factor analysis (Grahn & Stigsdotter, 2010) that identified eight factors, with differing numbers of variables. Because consideration of the full range of variables is essential to the operationalisation process, these are presented in Table 1. The

interpretations of the factors, as presented by Grahn and Stigsdotter (2010), can support understanding of the special characteristics of the various factors taken together. Practitioners who attempt to design on the basis of their interpretations alone often experience that these represent too vague a basis for design decisions. Table 1 also presents the factor loadings, indicating the strength of associations between the variables and each factor. Two variables in Factor 8 (PSD Serene) have caused some confusion because they are negatively loaded. The variables are: 'There are plenty of people and movements in the green space' (factor loading -0.78) and 'It is possible to watch other people being active, playing, practicing sports, etc.' (factor loading -0.69). These should be understood as indicating the opposite, i.e. 'There are not plenty of people and movements in the green space' and ''It is not possible to watch other people being active, playing, practicing sports, etc.'

In previous research (Grahn & Stigsdotter, 2010), the terms 'urban park' or 'urban open space' have been used to label the settings. In Table 1, the terminology has been changed to the broader term 'green space' because the 8 PSDs have been used in both research and practice at various scales and in various types of green spaces, not just in urban settings. For example, the PSDs have been used successfully in large-scale research projects at the regional level (Annerstedt, Östergren, Björk, Grahn, Skärbäck, & Währborg, 2012), including large forest areas; medium-scale projects at the city level (Skärbäck, Björk, Stoltz, Rydell-Andersson, & Grahn, 2014), including urban parks; and small-scale projects at the garden level (e.g. Palsdottir, Stigsdotter, Persson, Thorpert, & Grahn, 2018), including therapy gardens.

Practitioners have primarily used the 8 PSDs for three different functions: 1. To analyse which PSDs are present in different existing green spaces (Randrup, Schipperijn, Hansen, Jensen, & Stigsdotter, 2008), 2. To guide the redesign of existing green spaces (Stockholms läns landstings Regionplane- och trafikkontoret, 2004), and 3. In teaching and research, the 8 PSDs have been used in combination: a) To analyse the preconditions for green space, b) To guide the redesign process, and c) To evaluate the redesign in a post-occupancy evaluation (Sidenius, 2017).

Because the PSDs are context dependent, it is vital to understand a green space's context. The PSD Nature can be very strong in an urban park, though such a setting will not, of course, present this PSD at the same magnitude as in the wilderness of, for example, Yellowstone National Park. If the PSDs are used to analyse existing conditions, then the green spaces must be analysed on the basis of their contexts. This means that an urban park with a strong PSD Nature can achieve the highest graduation in strength. In order make the work transparent and comprehensible to others, it is therefore important to describe the context in one's own words.

It is necessary to determine where a PSD begins and ends. A research project involving four Danish municipalities prompted use of a classification system for different types of rooms in green spaces (Randrup, et al., 2008). The classification was originally developed by the Swedish researchers Gustavsson and Ingelög (1994) but was further developed by Randrup et al. (2008). In order to match Danish types of rooms in green spaces, a fourth type, Spread, was added to the original three (Randrup et al., 2008). The four types of rooms are characterised as follows: 1. Open, an open space without planting, 2. Spread, an open space with scattered planting, 3. Glade, a space formed by walls, but without a ceiling, and 4. Closed, a closed room in which tree branches form a ceiling (Figure 1). These room types may be helpful for identifying where one dominant PSD stops and the next PSD takes over. It is furthermore worth recalling that staff from both departments of nature and departments of health in four municipalities participated in the Danish study from 2008 (Randrup, et al., 2008). Exercises analysing existing PSDs in various green spaces showed consensus in results, regardless of the department at which informants were employed. This may indicate that the PSDs are relatable to people, no matter their training and educational backgrounds.

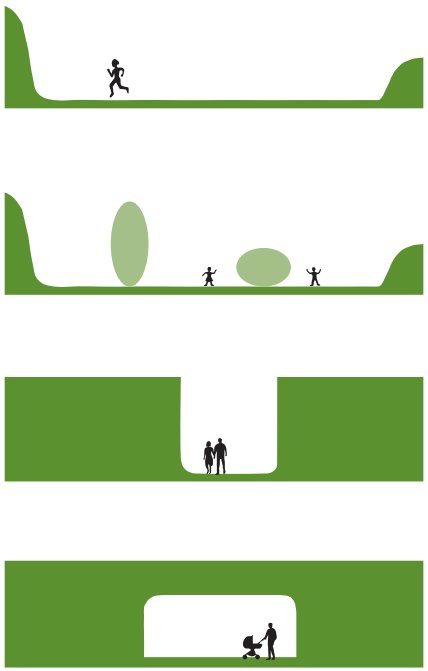


Figure 1: The four room types used in the 8 PSD health-promoting design tool. (Source: Randrup, et al., 2008)

As mention above, the PSDs are seldom found in isolation; one room can contain multiple PSDs. Nevertheless, one PSD is usually dominant or 'stronger' than the others. The non-dominant PSDs can support or potentially conflict with the dominant PSD. In the aforementioned example of the combination of PSDs constituting a restorative green space, the PSD Social conflicts with the combination of PSDs Refuge, Nature, and Rich in Species. The list of variables (Table 1) is useful for identifying a room's dominant PSD. It is often which PSD is dominant, but marking which variables are present makes the process transparent. A graduation for each PSD can be undertaken on the basis of this analysis. The graduation for each room is as follows: 0. Absence, the PSD cannot be identified, 1. Weak, the PSD can be poorly identified, 2. Moderate, the PSD can be identified but is not significant, 3. Strong, the PSD is very significant or cannot be found stronger. One can identify the dominant PSD in a room and give it a grade from 0 to 3 based on the present variables. One can then identify the other PSDs that are present and give them grades from 0 to 3 as well. This process of PSD identification and graduation in different rooms can be advantageously performed for different functions: 1. To analyse which PSDs are present in different existing green spaces, 2. To guide the redesign process, and 3. To evaluate the redesign in a post-occupancy evaluation.

Table 1: The variables and factor loadings for each factor/Perceived Sensory Dimension. The term 'green space' is used here (Source: Grahn & Stigsdotter, 2010)

Factor 1 – Nature	
Variables	**Factor loading**
The green space has a nature quality.	0.71
The green space has a wild and untouched quality.	0.63
There are free growing lawns.	0.54
It is possible to light a fire in the green space.	0.50
It feels safe spending time in the green space.	0.49
One is able to spend time in the green space without coming into contact with too many people.	0.47
The green space contains hilly areas.	0.44
Factor 2 – Culture	
Variables	**Factor loading**
The green space is decorated with fountains.	0.73
The green space is decorated with statues.	0.65
The green space contains a wide range of foreign plants, ornamental plants, and kitchen plants.	0.65
The green space has the characteristic of a city park.	0.57
The green space has different water features, such as ponds, canals.	0.52
The green space is ornamented with flowers.	0.50
The green space has a wooded pasture quality.	0.46
Factor 3 – Prospect	
Variables	**Factor loading**
The green space contains lawns and well-cut grass surfaces.	0.87
It is possible to gain an overview, with vistas over the surroundings.	0.78
The lawns are cut.	0.76
The green space has grass football pitches.	0.68
The green space has gravel football pitches.	0.50
The football pitches are lit up.	0.48
That green space has small ball grounds on asphalt.	0.47
Showers and changing rooms are available.	0.43
Factor 4 – Social	
Variables	**Factor loading**
It is possible to observe entertainment, like a park concert.	0.94
It is possible to observe exhibitions.	0.92
It is possible to visit a restaurant or a simple open-air restaurant in the green space.	0.89
It is possible to shop at market stalls, kiosks, etc.	0.78
There are plenty of people and movement in the green space.	0.74
The green space contains roads and gravel paths.	0.72
The green space holds special park animals, like swans, ducks and deer.	0.66
The green space has generally good lighting.	0.64
The roads are well lit.	0.63
There is access to washrooms.	0.60
There are places in the green space sheltered from the wind.	0.59

There are sunny places.	0.54
There are shady places.	0.52
The green space contains several seats and benches.	0.50
It feels safe spending time in the green space.	0.44
There are tables and benches.	0.38
The green space contains roads and paths with hard surfaces, such as asphalt, and concrete bricks.	0.33
Factor 5 – Space	
Variables	**Factor loading**
The green space is experienced as spacious and free.	0.89
It is possible to find areas not crossed by roads and paths.	0.87
The green space has numerous trees.	0.58
It is possible to find places where a group of several people can gather.	0.52
There are places in the green space sheltered from the wind.	0.49
There are sunny places.	0.44
There are shady places.	0.42
Factor 6 – Rich in species	
Variables	**Factor loading**
One can detect several animals, such as birds and insects.	0.97
The green space consists of natural plant and animal populations.	0.96
There are many native plants to study.	0.87
Factor 7 – Refuge	
Variables	**Factor loading**
The green space contains many bushes.	0.93
The green space holds animals that children and adults may feed and pet.	0.87
There are sand boxes.	0.77
There is play equipment, such as swings, slides, etc.	0.73
It is possible to watch other people being active, playing, engaging in sports, etc.	0.58
It feels safe spending time in the green space.	0.57
There are tables and benches.	0.36
Factor 8 – Serene	
Variables	**Factor loading**
The green space is silent and calm.	0.94
There are no bikes in the green space.	0.89
One is able to spend time in the green space without coming into contact with too many people.	0.84
There are plenty of people and movements in the green space.	−0.78
There are no mopeds.	0.74
It is possible to watch other people being active, playing, practicing sports, etc.	−0.69
The area is clean and well maintained.	0.60
There is no traffic noise from the surroundings.	0.57
It feels safe spending time in the green space.	0.50

2.2 Application of the 8 Psd Health-Promoting Design Tool in the Design of Health Forest Octovia®

In this study, the 8 PSD health-promoting design tool was used to guide the redesign of eight areas in an arboretum. The Hørsholm arboretum is located 30 kilometres north of Copenhagen and is regarded as Denmark's largest botanical collection of woody plants. Planted in relation to their geographical origins and generic affiliations, over 2000 species can be found in the arboretum (Jensen, 1994). The arboretum covers approximately 40 hectares and was established in 1936 (Jensen, 1994). Today the arboretum has the character of a majestic forest with exotic elements. There are three lakes in the arboretum, which attracts wildlife, especially birds. There were a number of advantages to establishing Health Forest Octovia® in an arboretum. The setting already possessed a natural and mature expression, and many of the 8 PSDs already existed. However, there were also some limitations. Since the arboretum is a highly valuable collection of trees and bushes, it was important not to damage the roots of the plants. This affected the placement of benches, new plantings, and paths. It was also impossible to change the expression of the planting by introducing plants that did not belong in the geographical area in question or to decorate or supply the area with sculptures, canals, or constructed shelters, washrooms, and other amenities that clashed with the arboretum's natural expression or collection.

Based on an analysis of existing variables for the PSDs (Table 1) during all four seasons, eight areas in the arboretum were identified as already good (Rich in Species, Space, Nature, Prospect, and Serene) or fairly good (Culture, Refuge, and Social) representations of the eight PSDs. During the design process, they were all redesigned to accentuate this particular sensory dimension. The borders of each area were identified using the classification system for different types of rooms in green spaces (Gustavsson & Ingelög, 1994; Randrup, et al., 2008) and are marked with a red line in Figure 2. With the help of a surveyor, the rooms were measured and marked on a map in great detail.

Figure 2: Site illustration of Health Forest Octovia®. Rooms are marked with a red line

The name Octovia was created specifically for the Health Forest and refers to the eight rooms connected by one path, deriving from the Latin octo (eight) and via (path/road). The rooms in Health Forest Octovia® were placed and numbered in accordance with their location along the path. The order of the PSDs thus differs from the order in the factor analysis (as presented in Table 1). Room 1 in Health Forest Octovia® represents the PSD Social, but this room also functioned as a gathering place, with information (signpost with text and QR code) about Health Forest Octovia® as a whole. All rooms had a signpost describing the current PSD and explaining how the room was designed. Entrances to all rooms were marked with a numbered granite stone placed on the ground. A similar stone marked the exit, and an arrow indicated the direction to the next room. All rooms also had seating. In Health Forest Octovia®, the rooms had the following order: 1. PSD Social, 2. PSD Prospect, 3. PSD Rich in Species, 4. PSD Serene, 5. PSD Culture, 6. PSD Space, 7. PSD Nature, and 8. PSD Refuge. In the following sections, the design of each PSD in Health Forest Octovia® will be transparently described, including site illustrations and tables describing each variable.

2.2.1 PSD Social

The room is designed to be prepared for visitors, where they could gather, eat, drink, have fun, and watch other people (Figure 3). It should be easy for visitors to get around in the room and find comfortable seating. The shape of the room is semi-circular. The walls consist of wood stacks, small trees, shrubs, and perennials. The location of the benches follows the room's semi-circular shape. The room opens up to the surroundings, and the room type is classified as Open. The floor consists of gravel and is directly connected to a gravel path. The open area enables several kinds of activities. The room has four long benches, some placed in the sun and others in the shade. The benches are placed so the visitors can watch other people in the room at the same time as they have a view of a good part of the arboretum. The wood stacks are located behind the benches, and their function is to create shelter from the wind, make the area feel safe, and define the room. Numerous birdhouses are placed in the trees and bushes behind the benches, with the aim of attracting some of the many birds that nest in the arboretum. A portable fire pit can be placed centrally in the room. The fire pit becomes a focal point but also allows for activities such as heating coffee and grilling sausages. In addition, the fire spreads heat, light, and a sense of security. Out of 17 variables, seven have been fulfilled, seven are partly fulfilled, and three are unfulfilled (Table 2). Bearing in mind the context and the limitations regarding what can be constructed, we conclude that the PSD Social dominates this room, and we grade the design as moderate (2). The PSDs Refuge and Rich in species are also present, though both are weak (1).

Table 2: Description of how the variables constituting the PSD Social were adopted in the design of Health Forest Octovia®

PSD Social – Room 1 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
It is possible to observe entertainment, like a park concert.	The larger open area in the room provides potential for various activities. The benches face the open area.		X	
It is possible to observe exhibitions.	The larger open area in the room provides potential for various activities.		X	
It is possible to visit a restaurant or a simple open-air restaurant in the green space.	It is not permitted to construct buildings in the arboretum, but a portable fire pit can be used to heat coffee or grill sausages.		X	
It is possible to shop at market stalls, kiosks, etc.	It is not permitted to build stalls or other constructions in the arboretum.			X
There are plenty of people and movement in the green space.	The arboretum has only approximately 25,000 visitors per year. The location of the room near the main road and the good overview of a large open area make it easy to discover other visitors.		X	
The green space contains roads and gravel paths.	The room is located in direct connection to a gravel path, and the main road of gravel is close by.	X		
The green space holds special park animals, like swans, ducks and deer.	The arboretum is rich in wildlife, and the birdboxes in the room are intended to attract birds.		X	
The green space has generally good lighting.	Electric lighting is not permitted in the arboretum, but it is quite a bright and open space, and the portable fire pit can contribute light.		X	
The roads are well lit.	Electric lighting is not permitted in the arboretum.			X
There is access to washrooms.	It is not permitted to build washrooms in the arboretum.			X
There are places in the green space sheltered from the wind.	The wood stacks behind the benches have the function of creating shelter from the wind.	X		
There are sunny places.	Some of the benches in the room are located in the sun.	X		
There are shady places.	Some of the benches in the room are located in the shade.	X		
The green space contains several seats and benches.	This room has the most benches of all rooms in Health Forest Octovia®.	X		
It feels safe spending time in the green space.	The benches are placed in a semicircle, so one can view other visitors. The fire pit in the middle of the room contributes to a feeling of security. From the room, visitors have a good overview, which can also contribute to security.	X		
There are tables and benches.	There are several benches in the room, but tables are not permitted in the arboretum.		X	
The green space contains roads and paths with hard surfaces, such as asphalt and concrete bricks.	It is the only room in Health Forest Octovia® that contains a solid surface of gravel, which is directly connected to a gravel path. Asphalt or similar are not permitted in the arboretum.	X		

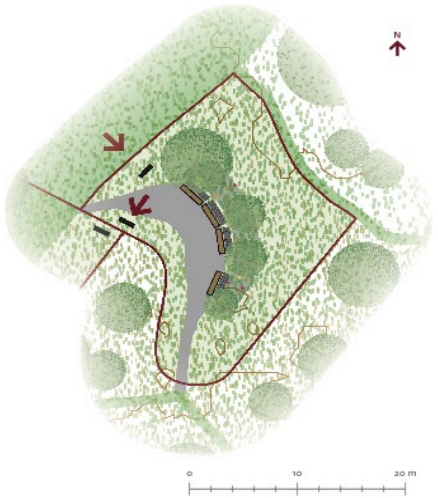


Figure 3: Site illustration of the PSD Social in Health Forest Octovia®

2.2.2 PSD Prospect

The room is designed to have two dominant qualities, in line with the variables (Figure 4). The first quality concerns open surfaces from which the visitor has views over his or her surroundings, while the other quality relates to surfaces and facilities for ball games. The room has an elongated rectangular shape, and the floor is flat with cut grass. The sides of the long sides consist of shrubs and trees. The room type is classified as Open. Views are open at each end of the room, with one view toward a large lake and the other toward the arboretum's main path. Two benches stand far apart in the room. One is placed so the visitor gets a good view over the room, and the other one is placed so the visitor gets a view of the lake. The room's openness makes it flexible, and it can be used for many activities, such as ball games. The PSD Prospect is dominant in this space and is graded as powerful (3) due to its context of an arboretum and not a sports area. This is motivated by the fact that the four variables with the strongest factor loading have been integrated into the design. The final four variables, which all focus on ball games, have not been possible to realise in the design (Table 3). No other supporting PSDs exist in this room.

Table 3: Description of how the variables constituting the PSD Prospect were adopted in the design of Health Forest Octovia®

PSD Prospect – Room 2 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
The green space contains lawns and well-cut grass surfaces.	The room is dominated by a large, rectangular lawn.	X		
It is possible to gain an overview, with vistas over the surroundings.	There are views from the benches into the room and toward the lake outside the room.	X		
The lawns are cut.	The lawns are cut regularly.	X		
The green space has grass football pitches.	The large lawn can be used as a football pitch.	X		
The green space has gravel football pitches.	It is not permitted to establish a gravel football pitch in the arboretum.			X
The football pitches are lit up.	Electric lighting is not permitted in the arboretum.			X
That green space has small ball grounds on asphalt.	Asphalt is not permitted in the arboretum.			X
Showers and changing rooms are available.	It is not permitted to build washrooms in the arboretum.			X

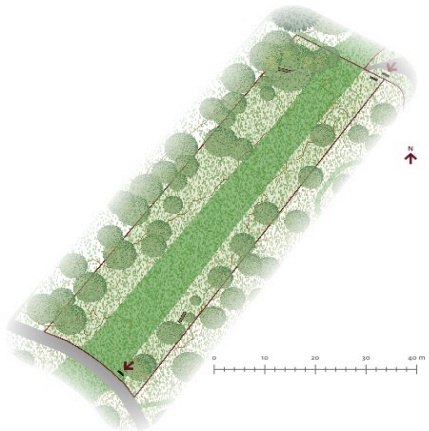


Figure 4: Site illustration of the PSD Prospect in Health Forest Octovia®

2.2.3 PSD Rich in Species

The room is designed to offer the visitor many forms of life (Figure 5). The walls of the room are made of trees and shrubs. The ground has a slight slope, rich flora, and a small pond. The room type is classified as Glade. The room is filled with greenery. The entrance and exit are between black and white

birch trunks. There is a great variety of species, with several kinds of trees, shrubs, perennials, grass, herbs, and bulbs. The plants vary in bark colour and texture as well as in leaf shape and colour, and they flourish at different times of year. They also attract different kinds of insects and small animals such as squirrels. The small pond attracts insects, frogs, salamanders, birds, rodents, and foxes. The numerous birdhouses also attract birds. Out of the three variables, the two with strongest loading have been fulfilled, and the one with the weakest loading is partly fulfilled (Table 4). Regarding the final variable, there are many different species in the room, but not all of them are native. We nevertheless grade the PSD Rich in Species as strong (3). Other PSDs present in the room are weak (1): Refuge, Space, and Serene.

Table 4. Description of how the variables constituting the PSD Rich in species were adopted in the design of Health Forest Octovia®

PSD Rich in species – Room 3 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
One can detect different animals, such as birds and insects.	The room has a great variety of plants and animals. It is easy to see the variety of plants due to characteristic textures and colours of the tree trunks and strong seasonal characteristics, such as brightly coloured flowers and fruits.	X		
The green space consists of natural plant and animal populations.	Trees, shrubs, and perennials are specifically chosen to attract animals. The small pond and birdhouses also fulfil this function.	X		
There are many native plants to study.	There are many different plants, but since we are in an arboretum, not all of them are native.		X	

Figure 5: Site illustration of the PSD Rich in Species in Health Forest Octovia®

2.2.4 PSD Serene

The experience of being undisturbed is reinforced by the room's placement slightly away from the main path and behind a large area with rhododendron (Figure 6). The entrance and exit are the same, and a narrow path leads down to a bench overlooking a large lake. The ground cover consists of natural greenery, and the walls are made of tall trees and shrubs. Treetops form the roof. The room type is classified as Closed, but the view of the lake prevents it from feeling cramped or dark. The room is oriented toward the lake, which is rich in birdlife. Neither fishing nor motorboats are allowed. The room is smaller than the others in Health Forest Octovia®. There is only one bench, which is shorter than a traditional bench. The intention of this is to signal that if there is already a visitor here, then others should continue their walk. It is a room designed for few visitors. The room is located in the quietest part of the arboretum. The view over the quiet lake creates a soothing feeling. The room is quiet with few people – a place for reflection. Eight of the nine variables have been fulfilled in the design, and one (with the second weakest loading) is partly fulfilled (Table 5). The PSD Serene is graded as strong (3), and the supporting PSDs are Rich in Species and Prospect (due to the view over the lake), both ranked as weak (1).

Table 5: Description of how the variables constituting the PSD Serene were adopted in the design of Health Forest Octovia®. Variables 3 and 5 on the list have been rephrased in order to avoid misunderstandings due to their negative factor loading

PSD Serene – Room 4 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
The green space is silent and calm.	The room is located some distance away from the main path, close to a big lake. There are no other roads or paths nearby. Motor boating or fishing in the lake is not permitted.	X		
There are no bikes in the green space.	It is not permitted to bike into the arboretum.	X		
One is able to spend time in the green space without coming into contact with too many people.	The room is small and private.	X		
There are not plenty of people and movements in the green space.	The room's design does not invite many people simultaneously. It is the smallest room in Health Forest Octovia® and is the only room where the visitor enters and leaves at the same place.	X		
There are no mopeds.	It is not permitted to ride a moped in the arboretum.	X		
It is not possible to watch other people being active, playing, practicing sports, etc.	The room is private and secluded.	X		
The area is clean and well maintained.	It is a small room that is being looked after.	X		
There is no traffic noise from the surroundings.	The room is located in one of the quietest parts of the arboretum, but there is sometimes sound from the remote motorway.		X	
It feels safe spending time in the green space.	The bushes behind the bench and the view of the room help make it feel safe.	X		

Figure 6: Site illustration of the PSD Serene in Health Forest Octovia ®

2.2.5 PSD Culture

The room has an elongated shape, and the floor consists of grass with a gravel path (Figure 7). The walls consist of bushes and perennials and some large trees. The type of room is classified as Open. The PSD Culture consists of several variables related to the experience of artificial elements that are shaped by humans, e.g. fountains, statues, and canals. These elements are not permitted in the arboretum since they would affect the general impression of the site. We instead needed to interpret the variables more creatively in the design. The arboretum is located on former agricultural land, and traces of human activity can still be found, namely the old gravel road, where the farmers led their cattle to the market in the nearby village. It is today seen as an elevation along the path that leads through the room. The room has two benches. One is oriented toward the elevation, and the other toward an ash tree, called 'V.1'. The tree is interesting because it is the first forest tree to be selected systematically for breeding work in Denmark. Many younger ash trees in the Danish forests descend from this tree. There are also numerous cultural-historical values related to the species, and in Nordic mythology the tree of life, Yggdrasil, was an ash tree. In other words, although the room is not decorated with cultural-historical objects, historical traces from a bygone era and the unique ash tree are important values. This makes it necessary to inform visitors about the room's story if they are to understand the cultural dimension. Out of seven variables, one (with weakest factor loading) is fulfilled, three are partly fulfilled, and three are unfulfilled in the design (Table 6). The PSD is thus graded as weak (1), though it improves to moderate (2) once the visitor has been informed about the elevation and the ash tree. The PSD Rich in Species can also be detected, though weakly (1).

Table 6: Description of how the variables constituting the PSD Culture were adopted in the design of Health Forest Octovia®

PSD Culture – Room 5 in Health Forest Octovia®				
Variables	Comments on adaptation of the variables in room design	Variables fulfilled in design		
		Yes	Partly	No
The green space is decorated with fountains.	It is not permitted to install fountains in the arboretum.			X
The green space is decorated with statues.	It is not permitted to install statues in the arboretum.			X
The green space contains a wide range of foreign plants, ornamental plants, and kitchen plants.	A large number of perennials and shrubs are planted as the boundary of the room.		X	
The green space has the characteristic of a city park.	The gravel path and the large trees provide the sense of an urban park.		X	
The green space has different water features, such as ponds and canals.	It is not permitted to construct large water features in the arboretum.			X
The green space is ornamented with flowers.	The new perennials contribute flower colours are but natural-like in expression.		X	
The green space has a wooded pasture quality.	The wild grass and perennials and the large trees give the experience of a wooded grazing area.	X		

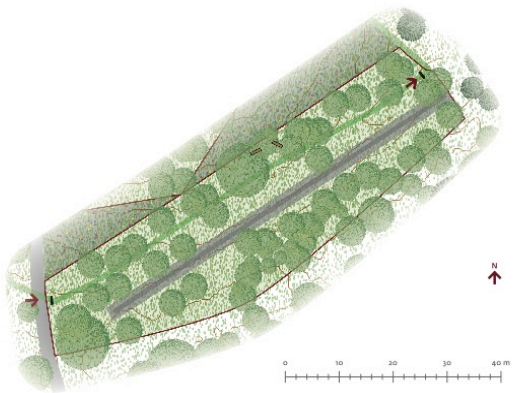


Figure 7: Site illustration of the PSD Culture in Health Forest Octovia®

2.2.6 PSD Space

The room has a rounded, coherent form (Figure 8). The floor consists of natural vegetation and the walls of shrubs. The roof is constituted by the treetops of medium-sized, multi-trunked trees and shrubs. The room type is classified as Closed. The path stays close to the edge and is made of wood chips so as to maintain the overall experience of the room. The room consists mostly of free-growing shrubs and trees. Together with the natural forest floor vegetation, they provide a coherent and undisturbed expression. The room has a distinctive character, which differs significantly from the other rooms. The visitor may experience it as entering another world. Two benches are located along the path where multiple people can gathered. Shrubs and trees allow for both shade and sun. Out of the seven variables, six have been fulfilled in the design, and one has been partly fulfilled (Table 7). The PSD Space is graded as strong (3), and the PSD Rich in Species can moderately be identified (2).

Table 7: Description of how the variables constituting the PSD Space were adopted in the design of Health Forest Octovia®

PSD Space – Room 6 in Health Forest Octovia®				
Variables	Comments on adaptation of the variables in room design	Variables fulfilled in design		
		Yes	Partly	No
The green space is experienced as spacious and free.	The room feels large and free. The borders are made of bushes, and it is hard to see the end of the room.	X		
It is possible to find areas not crossed by roads and paths.	There is only a small, discrete path (made of wood chips) that guides visitors along the edge of the room.	X		
The green space has numerous trees.	The room is dominated by multi-trunked trees.	X		
It is possible to find places where a group of several people can gather.	The room is large enough for several people to gather in it.	X		
There are places in the green space sheltered from the wind.	Bushes behind the benches stop the wind.		X	
There are sunny places.	There are places where the sun comes down through the treetops.	X		
There are shady places.	There are places where the treetops stop the sun's rays.	X		

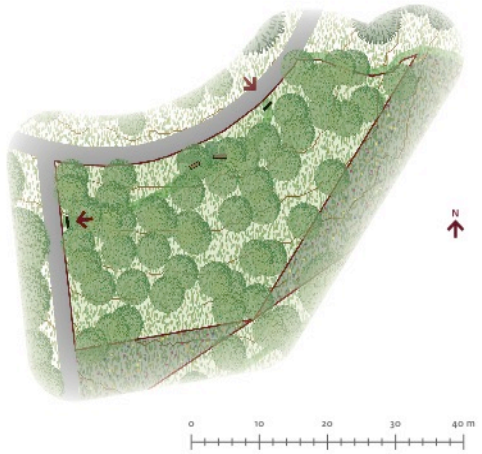


Figure 8: Site illustration of the PSD Space in Health Forest Octovia®.

2.2.7 PSD Nature

The room is distant from larger footpaths. A narrow grass trail leads up a small hill to the room, which has a natural form (Figure 9). The walls mainly consist of large, dark-green conifers. The ground vegetation layer is made of natural forest flora, such as moss and ferns. The room type is classified as Closed. Two benches are located close to tall spruce trees. The large fir trees, mossy stones, and natural forest ground cover give an impression of a naturally growing North Scandinavian spruce forest. Visitors must move deeper and deeper into the forest to reach the benches. Nature is experienced as powerful: it is the one that is in control. The route of the path and location of the benches have been formed by nature. At the same time, the trees create security due to their age and size. Out of the seven variables, five has been fulfilled in the design, and only one has not been fulfilled due to the fact that it

is not permitted to light fires close to the trees in the arboretum (Table 8). The PSD Nature is graded as strongly (3) represented in this room, and the PSDs Refuge, Rich in Species, and Space can be weakly (1) identified.

Table 8: Description of how the variables constituting the PSD Nature were adopted in the design of Health Forest Octovia®

PSD Nature – Room 7 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
The green space has a natural quality.	The room has a North Scandinavian natural forest character.	X		
The green space has a wild and untouched quality.	It has the appearance of a free-growing pine forest.	X		
There are free-growing lawns.	The grass is uncut.	X		
It is possible to light a fire in the green space.	It is not permitted to light a fire under the trees in the arboretum.			X
It feels safe spending time in the green space.	The large, old trees create a sense of security.	X		
One is able to spend time in the green space without coming into contact with too many people.	Many small, pre-existing paths has been blocked by vegetation. The massive vegetation makes it hard to see and sense the end of the room even though the room is of limited size.	X		
The green space contains hilly areas.	The room has naturally hilly terrain.		X	

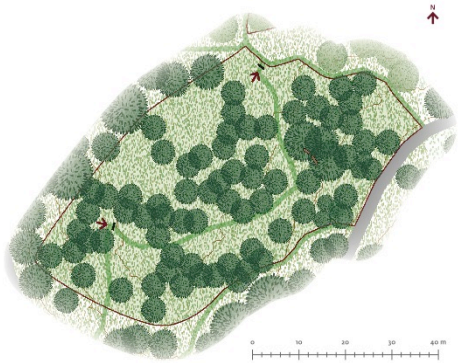


Figure 9: Site illustration of the PSD Nature in Health Forest Octovia®

2.2.8 PSD Refuge

This PSD varies depending on whether the visitor is a child or an adult. For children, Refuge is about being able to play freely and safely. For adults, it is more about daring to let the child play freely and being able watch the child from a safe place. Alternatively, it is about the adult being able to sit and watch others who are being active. This is why the room is discreetly divided into two parts (Figure 10). The part of the room designed for adults is furnished with two small benches, from which various bushes and perennials can be viewed. The room has clear boundaries, with numerous shrubs creating 'protection in the back'. However, there is dense beech growth behind where the children's area or territory. The adults' section of the room is classified as Open, while the children's section is classified as Closed. Since it is not permitted to build play equipment in the arboretum, a unique beech tree with long, curved branches serves 'climbing equipment'. Out of the seven variables, three have been fulfilled, two have been partly fulfilled, and two have not been fulfilled (Table 9). Both areas of the room are graded as moderate (2). In the adults' section, the PSD Rich in Species can also be weakly (1) identified, and in the children's section, the PSD Space can be weakly (1) identified.

Table 9: Description of how the variables constituting the PSD Refuge were adopted in the design of Health Forest Octovia®

PSD Refuge – Room 8 in Health Forest Octovia®				
Variables	**Comments on adaptation of the variables in room design**	**Variables fulfilled in design**		
		Yes	**Partly**	**No**
The green space contains many bushes.	The room is defined by bushes.	X		
The green space holds animals that children and adults may feed and pet.	The arboretum cannot keep domestic animals.			X
There are sand boxes.	Sand boxes are not permitted in the arboretum.			X
There is play equipment, such as swings, slides, etc.	It is not permitted to install play equipment. However, the room has a unique tree that attracts children to climb.		X	
It is possible to watch other people being active, playing, engaging in sports, etc.	From the secluded benches, it is possible to observe others who are active in the room or on the path.	X		
It feels safe spending time in the green space.	The bushes behind the benches and the view of the main path give a sense of security.	X		
There are tables and benches.	There are benches, but tables are not permitted in the arboretum.		X	

Figure 10: Site illustration of the PSD Refuge in Health Forest Octovia®

3. RESULTS AND DISCUSSION

The operationalisation of the 8 PSDs resulted in a six-step health-promoting design tool (Figure 11) as well as in a list of variables and factor loadings for each PSD (Table 1). The guide consists of the following six steps:

• *Step 1. Determine the aim of the PSDs: analysis and/or design tool*. The 8 PSDs can be used both as an analytical (pre-design and post-design) method and a design tool. They can also be used advantageously to both analyse and design green spaces.

• *Step 2. Determine the scale at which you operate*. The 8 PSDs can be used at different scales. They have been used successfully at both larger and smaller scales. One must determine in which scale one operates: Large Scale (regional level), Medium Scale (city level), or Small Scale (garden level).

• *Step 3. Identify context*. It is crucial to understand the green space's context. The PSDs are context dependent, and it is therefore important to describe the context. Everything is analysed on the basis of the context in which it is located. As such, it is possible for a city park with a strong presence of Nature to achieve the highest grade (3).

• *Step 4. Identify existing rooms*. The four room types may be helpful when identifying where one PSD begins and where the next PSD takes over. The four types of rooms are characterised as follows: 1. Open: an open space without planting; 2. Spread: an open space with scattered planting; 3. Glade: a space formed by walls, but without a ceiling; and 4. Closed: a closed room in which tree branches form a ceiling.

• *Step 5. Identify and graduate existing PSDs*. One room can contain multiple PSDs. One PSD is usually dominant or 'stronger' than the others. Start by identifying the dominant PSD. Take the list with all the variables that constitute the different PSDs, and mark all the variables that are present in the room. The graduation for each room is as follows: 0. Absence: the PSD cannot be identified; Weak: the PSD can be poorly identified; Moderate: the PSD can be identified but is not significant; 3. Strong: the PSD is very significant or cannot be found stronger. One can identify the dominant PSD in a room and give it a grade from 0 to 3 based on the present variables. One can then identify the other PSDs that are present and give them grades from 0 to 3 as well.

• *Step 6. Start design phase*. Once one has decided which PSD one wishes to reinforce or establish, it is time to once again consider the actual natural qualities (the variables in the factor analysis) that form the PSD.

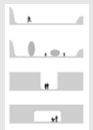
Steps	Actions	Guide to working process
1	Determine the aim of the PSDs	• Analytical tool • Design tool • Combined analytical and design tool
2	Determine the scale in which you operate	• Large Scale (region level) • Medium Scale (city level) • Small Scale (garden level)
3	Identify the context	Describe the context in own words
4	Identify existing rooms	• Open • Spread • Glade • Closed 
5	Identify and graduate existing PSDs	• Which is the dominant PSD in each room? (Use the list of all the variables that constitute the different PSDs) • Graduate it from 0-3 (0=absent; 1=weak; 2=moderate; 3=strong) • Are other PSDs present in the same room? • Graduate each of the other PSDs.
6	Start design phase	Based on the first five steps, decide which PSDs you wish to strengthen, weaken, or remove.

Figure 11: The 8 PSDs health-promoting design tool

Both the EU and the WHO call for nature-based solutions and interventions to manage challenges (for instance, involving mental human health) associated with today's rapid urbanisation. In this context, there is a need for an easily applicable design tool for landscape architects and urban planners. The current study aims to describe the operationalisation of the PSDs into an applicable design tool for practitioners. The tool seeks to promote mental health by offering visitors nature experiences that they prefer and in which they can mentally restore themselves. The 8 PSD health-promoting design tool could thus function as an evidence-based design tool for 'nature-based solutions' and could enhance sustainable urbanisation by promoting residents' mental health. Since the establishment of Health Forest Octovia®, research has confirmed the effectiveness of the PSD health-promoting design tool (Stigsdotter, et al., 2017a; Stigsdotter, et al., 2017b). This can be seen as an initial validation by research, but the PSD health-promoting design tool also needs to be validated through application to other design projects.

The 8 PSDs have been used in research in various parts of the world, including the Nordic countries (Lindholst et al., 2015; Plambech & Konijnendijk van den Bosch, 2015); Estonia (Maikov, 2013); Russia and China (Skärbäck &

Grahn, 2016); Canada (Lockwood, 2017); Malaysia (Mansor et al., 2017); Serbia (Vujcic & Tomicevic-Dubljevic, 2017; 2018); and Iran (Memari et al., 2017). We assume that the PSDs are universal. However, it would be desirable to repeat the original questionnaire in areas outside Scandinavia and re-perform the original factor analysis (Grahn & Stigsdotter, 2010) in order to ensure that they actually are universal and to check whether any variations can be detected. It is furthermore considered a strength that the 8 PSD health-promoting design tool demonstrates respect for existing contexts and conditions. The tool focuses on existing qualities of green spaces that may be strengthened, meaning that it is often the case that no trees need to be chopped down, and no bushes need to be pulled up. The PSD health-promoting design tool guides the landscape architect or planner to work with that which already exists.

4. CONCLUSION

The current study aims to describe the operationalisation of the Perceived Sensory Dimensions (PSDs) within an applicable design tool. The PSDs are a result of previous research indicating that people perceive green spaces in terms of eight dimensions, some of which are more important than and preferred to others when it comes to promoting mental restoration. This paper argues that the 8 PSD health-promoting design tool may be useful for designing mental health-promoting green spaces. In parallel with the design process of the Health Forest Octovia® research and demonstration site, a stepwise model for applying the PSDs in practice was developed. The operationalisation of the 8 PSDs resulted in a six-step health-promoting design tool. The six steps are: 1. Determine the aim of the PSDs: analysis and/or design tool, 2. Determine the scale at which you operate, 3. Identify context, 4. Identify existing rooms, 5. Identify and graduate existing PSDs, and 6. Start design phase. Based on the results from a study in Health Forest Octovia®, the PSD health-promoting design tool seems effective. Further validation, however, requires that it be applied to other design projects.

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