Gardening Promotes Neuroendocrine and Affective Restoration from Stress

AGNES E. VAN DEN BERG
Wageningen University and Research Center, The Netherlands
MARIËTTE H.G. CUSTERS
Leiden University & Wageningen University and Research Center, The Netherlands

JHP

Journal of Health Psychology

Los Angeles, London, New Delhi, Singapore and Washington DC
www.sagepublications.com
Vol 16(1) 3–11
DOI: 10.1177/1359105310365577

Abstract

Stress-relieving effects of gardening were hypothesized and tested in a field experiment. Thirty allotment gardeners performed a stressful Stroop task and were then randomly assigned to 30 minutes of outdoor gardening or indoor reading on their own allotment plot. Salivary cortisol levels and self-reported mood were repeatedly measured. Gardening and reading each led to decreases in cortisol during the recovery period, but decreases were significantly stronger in the gardening group. Positive mood was fully restored after gardening, but further deteriorated during reading. These findings provide the first experimental evidence that gardening can promote relief from acute stress.

ACKNOWLEDGEMENTS. This research was supported by a grant from the Netherlands Organization for Scientific Research [NWO 474-03-435].The authors thank Marijke van Winsum-Westra and Jolanda Maas for help with data collection and other useful contributions to the research, Mieneke Weenig for helpful discussions and guidance, Bart Ballieux for chemical analysis of cortisol, Sander Koole for useful comments on previous drafts of the paper, and the board and members of the allotment complex Amstelglorie for their willingness to participate in this project.

COMPETING INTERESTS: None declared.

ADDRESS. Correspondence should be directed to:
AGNES VAN DEN BERG, Wageningen University and Research Centre, PO Box 47, 6700 AA Wageningen, The Netherlands.
[email: agnes.vandenberg@wur.nl]

Keywords

- *activity*
- *health promotion*
- *intervention*
- *lifestyle*
- *well-being*

Gardening has traditionally been associated with stress relief, and many individuals say that gardening helps them relax and recover from the hassles of everyday life (Francis & Hester, 1992; Gross & Lane, 2007; Milligan, Gatrell, & Bingley, 2004). Indeed, relaxation and stress relief are among the primary self-reported reasons why people engage in gardening (Armstrong, 2000; Catanzaro & Ekanem, 2004; Clayton, 2007; Dunnett & Qasim, 2000). Based on these self-reports, gardening has become recognized as a 'restorative activity' that provides effective relief from stress and mental fatigue (Kaplan & Kaplan, 1989). As yet, there is no direct evidence for a causal impact of gardening on relief from stress. However, several lines of research provide suggestive evidence for the stress-relieving effects of gardening.

As a physical activity of moderate (3.8 ± 1.4 metabolic equivalents) intensity (Park, Shoemaker, & Haub, 2008), gardening is routinely included in correlational studies on the health benefits of exercise. These studies have consistently shown that regular engagement in gardening and other forms of moderate exercise is related to reduced reactivity to stress (Weyerer & Kupfer, 1994), lower likelihood of depression (Teychenne, Ball, & Salmon, 2008), and decreased risk of stress-related diseases such as cardiovascular disease (Lemaitre et al., 1999) and type 2 diabetes (Jeon, Lokken, Hu, & van Dam, 2007). For example, one study revealed that individuals who performed only gardening activities for more than 60 minutes per week had 66 percent less chance of primary cardiac arrest than individuals who were physically inactive (Lemaitre et al., 1999). These findings suggest that gardening may have a stress-relieving impact, at least when practiced over a longer period of time.

A second line of evidence suggestive of the stress-relieving effects of gardening comes from research on the restorative effects of nature. Restorative effects of interactions with natural environments, such as gardening or visiting the outdoors, have been recognized and used for therapeutic purposes since antiquity (Simson & Straus, 1998). These long-standing notions and practices are increasingly substantiated by well-controlled research. For example, recent epidemiological studies have shown that green living environments are associated with lower morbidity and mortality, in particular from stress-related diseases such as anxiety disorders and depression (Maas et al., 2009; Mitchell & Popham, 2008). In addition, there is substantial experimental evidence for the restorative effects of nature (Van den Berg, Hartig, & Staats, 2007). Such effects have been demonstrated in laboratory experiments which presented slides or videos to acutely stressed individuals (Ulrich et al., 1991; Van den Berg, Koole, & van der Wulp, 2003) as well as in field experiments in which stressed participants walked through a natural area (Hartig, Evans, Jamner, Davis, & Garling, 2003), visited a garden (Ottosson & Grahn, 2005; Rodiek, 2002), or engaged in organized horticultural therapy programs (Gigliotti, Jarrott, & Yorgason, 2004; Wichrowski, Whiteson, Haas, Mola, & Rey, 2005). For example, one experiment showed that feelings of anger, tension and depression, which had been elevated by a frightening movie, were reduced by 38 percent in participants who viewed a video of a natural environment, whereas participants who viewed an urban video only showed a 17 percent reduction in negative feelings (Van den Berg et al., 2003).

In sum, prior research on gardening and stress relief has been primarily descriptive and based on self-reports of gardeners. Research on the health benefits of exercise and the restorative effects of nature provides some suggestive evidence for more controlled research that gardening can promote relief from stress. As yet, however, the causal impact of common domestic gardening activities on recovery from stress has not been directly empirically demonstrated.

The present research

The present research consisted of a field experiment in which we first induced stress and then experimentally varied whether people engaged in gardening activities. This design allowed us to determine whether gardening has a causal impact on recovery from stress. We hypothesized that gardening, due to its combination of exercise and contact with nature, would be more effective in promoting stress relief than a control activity, which consisted of an indoor reading task.

Besides addressing the causal impact of gardening on stress relief, the present experiment went beyond prior research in several ways. First, prior research on gardening has relied mostly on self-reports from gardeners on their gardening experiences, which may be prone to memory bias and other sources of inaccuracy. To overcome these limitations, the present experiment examined gardeners in real time as they actually engaged in gardening activities. Second, prior research on the restorative effects of contact with nature has mostly used self-reported mood measures and general, external physiological indicators of stress (heart rate, blood pressure, GSR). In the present experiment we sought to advance beyond this research by studying salivary cortisol responses as one of the most robust endocrine biomarkers of stress (Hellhammer, Wust, & Kudielka, 2009). Third and last, past research has examined organized gardening activities in shared or public gardens, which arguably represent a somewhat artificial context. To more closely approximate common domestic gardening, we conducted the present experiment on an allotment complex with private plots of similar size and form. In this way, we were able to examine individual gardening activities on private premises in a controlled but realistic manner.

Method

Participants and design

Participants were recruited among the members of the allotment complex 'Amstelglorie' in Amsterdam, the Netherlands. Amstelglorie is a large complex of about 21 hectares containing 440 plots with wooden homes and permission for overnight stay. The complex is used mostly for recreational and social activities, and the majority of gardens are ornamental gardens with terraces and borders. A total of 30 healthy plot holders (eight men, 22 women), with a mean age of 57.6 years (range 38–79) volunteered.

After performing a stressful task, participants were randomly assigned to 30 minutes of either outdoor gardening activities or indoor reading. Randomization was blocked by gender and sessions, which started at 10.30 (14 participants), 13.00 (11 participants) and 15.30 hrs (five participants). The first session was scheduled mid-morning to avoid the morning peak value of salivary cortisol (Fries, Dettenborn, & Kirschbaum, 2009). Overall, there were 14 participants (mean age 58.29 years, SD = 8.49) in the gardening condition and 16 participants (mean age 57 years, SD = 8.49) in the reading condition. In the gardening group, 28 percent of the participants were male, 21.4 percent were smokers, 7.1 percent used medication, 50 percent of the participants had a paid job, and 64.3 percent were educated at pre-university level or higher. In the reading group, 25 percent of the participants were male, 12.5 percent were smokers, 18.8 percent used medication, 43.9 percent had a paid job, and 69.8 percent were educated at pre-university level or higher. There were no reliable differences between the two groups on any of the measured health or socio-demographic characteristics.

Stress induction

Mental stress was induced using a Stroop task with a social comparison and evaluation component (Macleod, 1991). This computer-administered task consisted of 10 test trials and 200 experimental trials. In each trial, the word 'red' or 'blue' appeared on the screen of a laptop. Participants had to identify the color of the word by hitting two selected keys from the keyboard. A false feedback message was displayed after 100 trials, stating that participants' performance was below the average of other individuals of their age and gender. After 200 trials, a final score between 1 (low) and 10 (high) was presented, which was manipulated so that the maximum was a 7. To add an element of social evaluation, participants were asked to show their low score to the experimenter, so that she could record it.

Measures

Cortisol was assessed from saliva, a non-invasive approach useful for repeated measurements in field settings (Kirschbaum & Hellhammer, 1994). Saliva was collected with Sarstedt Salivettes®, which consist of plastic tubes containing a cotton wool swab on which participants had to chew for one minute. Saliva samples were collected shortly after arrival at the experimental location, before the stressful task, after the stressful task, halfway through the experimental activity, and after the experimental activity. The first sample upon arrival was intended to familiarize the participant with the procedure and not analyzed. Samples were kept frozen during the experiment and then sent to a laboratory at Leiden University. Cortisol concentrations were determined using Elecsys 2010 (Roche Diagnostics, Mannheim, Germany) with functional sensitivity of 2 nmol/l (Van Aken, Romijn, Miltenburg, & Lentjes, 2003).

Mood was measured by a Dutch translation of the Positive and Negative Affect Schedule (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS consists of 10 positive (e.g. enthusiastic, active, proud) and 10 negative (e.g. irritable, frightened, ashamed) mood words. Participants completed a written version of the PANAS prior to the stressor, after the stressor, and after the experimental activity. Item order was varied across the three versions.

Participants rated the extent to which they currently experienced each feeling on a 5-point scale (1 = Very slightly or not at all, 2 = A little, 3 = Moderately, 4 = Quite a bit, 5 = Extremely). The mean of the 10 positive items was used as a measure of positive mood (Cronbach's alpha between 0.87 and 0.91) and the mean of the 10 negative items was used as a measure of negative mood (Cronbach's alpha between 0.81 and 0.86). Post-stress PANAS data were missing for one participant in the gardening condition because of experimenter error.

Activities and procedure

Data collection took place during two weeks in late April and early May; in each condition, the weather was cloudy and dry, with a few spells of rain and sunshine. Prior to the experiment, participants had received a letter in which they were asked not to eat, smoke or drink coffee two hours before the experiment (Hansen, Garde, & Persson, 2008). Participants were individually tested on their own allotment plot by one of three trained (female) experimenters.

Upon arrival at the plot, the experimenter gave a short introduction to the study. Participants next read and signed a consent form. Participants were also given a Salivette to get acquainted with saliva collection. They then started with the first sequence of pre-stressor PANAS and cortisol measures, after which they performed the stressful task for about 25 minutes and completed a second series of post-stressor PANAS and cortisol measures. Subsequently participants were instructed to perform the experimental activity. In the gardening condition, participants carried out light activities such as pruning of plants and bushes, weeding and the removal of dead flowers, sowing or planting on their own plots. Heavy activities, such as cutting of large branches or digging were not allowed. In the reading condition, participants read popular magazines that were screened for the absence of visual or verbal contents related to nature. Participants were seated in a comfortable location in their own allotment home that did not provide a view of nature. During the task, participants were not allowed to talk in person or by phone to other persons. A third cortisol sample was collected midway during the experimental activity. After completing the experimental activity, participants completed the last series of PANAS and cortisol measures. Participants concluded the procedure by filling out a questionnaire on their health and socio-demographic background. Finally, participants were thanked and paid €12.50 for their participation. The total duration of each session was approximately 1.5 hours.

Data analysis

All analyses were carried out using SPSS for Windows (version 15.0). Square root transformations were applied to the cortisol data before statistical analysis to normalize distributions. Repeated-measures Analyses of Variance (ANOVAs) with condition (reading, gardening) as the between subjects factor were used to determine reactivity and recovery rates of positive and negative mood and cortisol. Baseline scores were included as a planned covariate in all analyses of recovery rates of cortisol and mood. Session was included as an additional planned covariate in analyses of recovery rates of cortisol. Post-hoc tests of between and within group differences in covariate-adjusted means were performed when significant condition by time interactions were found. Instead of the partial eta squared provided in the SPSS output, we calculated eta squared ($\eta 2$) as a more easily interpretable measure of effect size that is roughly equal to the proportion of explained variance in the sample (Levine & Hullett, 2002).

Results

Stress induction

Across the two conditions, cortisol levels were significantly higher after the stressful task, $M = 6.94$, SD = 1.96, than at baseline, $M = 5.40$, SD = 1.94, F (1, 28) = 39.04, $p < .01$, $\eta^2 = .58$. Positive mood was significantly lower after the stressful task, $M = 3.37$, SD = .65, than at baseline, $M = 3.61$, SD =.54, F (1, 27) = 9.26, $p < .01$, $\eta^2 = .24$. Negative mood was somewhat higher after the stressful task, $M = 1.54$, SD = .51, than at baseline, $M = 1.43$, SD =.49, however, this difference was not significant F (1, 27) = 3.0, $p = .16$, $\eta^2 = .07$. Thus, the stress manipulation was successful in raising cortisol levels and lowering positive mood, but did not have a significant effect on negative mood.

The two groups did not significantly differ on any of the dependent variables at baseline, all ps > .11, or after the stress induction, all ps > .38. The effects of the stressful task did not differ across conditions, all ps > .18 (see Table 1).

Effects of gardening and reading

The analysis of salivary cortisol levels during recovery (with baseline cortisol and session as

Table 1. Untransformed means and standard deviations for study variables by condition

	Baseline M (SD)	*Post-stress M (SD)*	*Mid-activity M (SD)*	*Post-activity M (SD)*
Gardening (n = 14)				
Cortisol	5.10 (1.77)	6.69 (2.07)	5.87 (2.17)	5.24 (2.26)
Positive mood	3.78 (0.53)	3.44 (0.52)	–	3.70 (0.48)
Negative mood	1.35 (0.51)	1.49 (0.52)	–	1.22 (0.41)
Reading (n = 16)				
Cortisol	5.67 (2.09)	7.16 (1.90)	6.64 (2.34)	6.37 (2.22)
Positive mood	3.45 (0.54)	3.31 (0.76)	–	3.21 (0.70)
Negative mood	1.51 (0.48)	1.59 (0.51)	–	1.35 (0.42)

covariates) revealed a significant condition by linear trend interaction, F (1, 26) = 4.48, $p < .05$, $\eta^2 = .07$, illustrated in Figure 1, top graph. Cortisol decreased significantly from post-stressor to post-activity in the gardening group, F (1, 11) = 24.15, $p < .001$, and the reading group, F (1, 13) = 5.33, $p < .05$, indicating that both activities were relaxing at the physiological level. However, cortisol levels decreased to a greater extent in the gardening than in the reading condition, especially during the second half of the activity. In the latter phase, there was a significant decrease in cortisol in the gardening group, F (1, 11) = 7.02, $p < .05$, whereas in the reading group the decline in cortisol from mid-activity to post-activity was not significant, $p = .20$. Both groups did not differ at post-stress, $p = .36$, and mid-activity cortisol, $p = .27$. However, at post-activity, cortisol was marginally lower in the gardening group than in the reading group, F(1, 27) = 3.21, $p = .08$.

Repeated measures analyses of recovery ratings of positive mood with condition as independent variable and baseline positive mood as a covariate revealed a significant condition by time interaction F (1, 26) = 4.35, $p < .05$, $\eta^2 = .13$, illustrated in Figure 1, bottom graph. Positive mood increased significantly from post-stress to post-activity by 9.2 percent in the gardening group, F (1, 12) = 4.91, $p < .05$, but dropped by 4.3 percent in the reading group; this latter decrease was, however, not significant, $p = .53$. The two groups did not differ at post-stress, $F < 1$, but at post-activity positive mood was significantly higher in the gardening group than in the reading group, F (1, 28) = 4.93, $p < .05$.

To gain more insight into the relationship between cortisol and positive mood, we computed correlations between changes in cortisol from post-stress to post-activity and the corresponding change score for positive mood in each of the two groups. Changes in cortisol and positive mood were significantly negatively related in the gardening group, $r = -.51$, $p < .05$, whereas they were significantly positively related in the reading group, $r = .55$, $p < .05$. The difference between both correlations was significant, $z = 2.88$, $p < .01$.

Negative mood slightly decreased from post-stress to post-activity in both conditions. However, repeated measures analyses of recovery ratings of negative mood (with baseline negative mood as covariate) showed no significant effects of time, neither as a main effect nor in interaction with condition, both Fs < 1. In addition, changes in negative mood from post-stress to post-activity were not significantly related to corresponding changes in cortisol, $r = .03$, $p = .88$, or positive mood, $r = -.22$, $p = .26$. Overall, ratings of negative mood were very low (range 1–2.8 on a scale of 1–5) and exhibited little variation across measurement points or conditions. The absence of effects on negative mood of the experimental manipulations thus appears to reflect a low sensitivity of the measurement scale, which may be due to the fact that negative mood items of the PANAS are relatively extreme and may be less applicable to mood states of healthy participants.

Discussion

The present research tested the hypothesis that gardening can promote restoration from stress. To this end, allotment gardeners were first exposed to a stressful task and then randomly assigned to conditions of gardening on their own allotment or reading in their own allotment home. In line with expectations, gardening promoted stronger

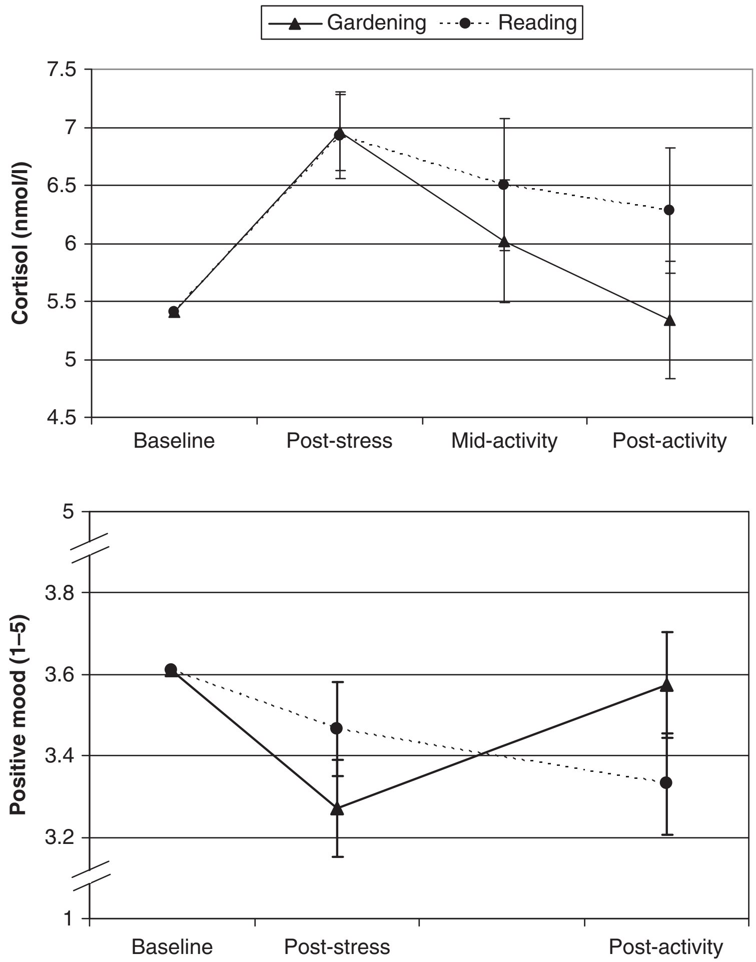

Figure 1. Untransformed means of salivary cortisol (top) and positive mood (bottom) in the two conditions. Baseline values represent the average scores across the entire sample. Post-stress, mid-task, and post-task values are estimated at these fixed baseline scores. Cortisol values are adjusted for the influence of session.

psycho-physiological recovery from stress than indoor reading. After 30 minutes of gardening, levels of salivary cortisol and self-reported positive mood had fully returned to baseline. A comparable amount of indoor reading also led to some reduction of cortisol levels, but this reduction was weaker and not accompanied by an increase in positive mood. Unexpectedly, negative mood was insensitive to the experimental manipulations, possibly because the negative mood items of our assessment were too extreme for participants to regard them as applicable to themselves. Overall, the present results provide the first experimental evidence for the effectiveness of gardening as a means of relieving acute stress.

The present findings are compatible with correlational research on the health benefits of exercise, which indicates that regular engagement in gardening as a moderate type of exercise is related to reduced reactivity to stress and lower likelihood of depression and stress-related disease (Teychenne et al., 2008; Weyerer & Kupfer, 1994). In the exercise literature, there has been some debate on the effectiveness of single bouts of moderate exercise in reducing acute stress. Whereas some studies have reported decreased levels of psychological and physiological stress after a single bout of moderate exercise, others have reported increased levels or no changes (Salmon, 2001; Thompson et al., 2001). The present study informs this debate by showing that a brief period of gardening, as a specific form of nature-based moderate exercise, can provide psycho-physiological restoration from acute stress.

The present findings also fit well with a larger body of research showing that contact with nature is related to lower mortality and morbidity from stress-related diseases and stronger recovery from acute and chronic stress (Maas et al., 2009; Mitchell & Popham, 2008; Van den Berg et al., 2007). Research on the restorative effects of nature has thus far focused mostly on visual and incidental forms of contact with nature, such as viewing pictures of nature or walking through a park. The present study adds to this literature by showing that gardening, as a more involved and goal-directed way of interacting with nature, can have similar stress-relieving effects. This is important, because engaging in goal-directed activities can stimulate people to regularly make contact with nature and to spend prolonged periods of time in a natural environment (Francis & Hester, 1992). Gardening may thus permit people to enjoy the restorative effects of nature on a regular basis.

The present study pioneers an experimental approach to the stress-relieving effects of gardening. As such, the present research is not without limitations. Due to constraints in time and resources, we were able to include only one control condition. We selected indoor reading of magazines as a control condition that would give an indication of the effectiveness of gardening in its full dimensionality against a commonly practiced alternative relaxation activity. However, because indoor reading is both passive and non-natural, the relative contribution of the natural environment and physical activity components of gardening could not be determined. In addition, indoor reading might have been somewhat aversive to gardeners in the present study, by keeping them from gardening in their own allotment plot. We recommend follow-up studies to compare the effects of gardening against more specific control activities that allow more insight into the mechanisms underlying these effects, such as moderate exercise in a quiet urban environment, or passive contemplation of nature. To further examine the role of exercise in the stress-relieving effects of gardening, future studies could also incorporate heart rate monitors and accelerometers.

By conducting a field experiment among allotment gardeners, the present study found a feasible and externally valid way to investigate the restorative effects of tending one's own garden. However, by the same arrangement, it is possible that we mostly included people who were particularly sensitive to the psycho-physiological benefits of gardening. Moreover, the present study focused on allotment gardeners, a group with specific interests and characteristics. This warrants caution in generalizing findings to other samples. An important task for future research will be to replicate the results of the current study with different groups of gardeners and non-gardeners. In so doing, future research should preferably include larger samples that allow for the identification of characteristics such as gender, age, physical condition, skill, or interests that may moderate the restorative effects of gardening.

Eventually, longitudinal studies will be needed to examine how the psycho-physiological effects of gardening unfold over time. Such longitudinal studies could adopt paradigms from exercise research to investigate reactivity to stressful tasks before and after prolonged engagement in gardening programs, specifically in populations that are currently not engaging in this activity (e.g. Storch, Gaab, Kuttel, Stussi, & Fend, 2007). In doing so, longitudinal studies may provide important additional information on the potential stress-buffering effects of gardening, which are suggested by recent epidemiological research (Van den Berg, Maas, Verheij, & Groenewegen, 2010). Longitudinal studies also allow for examining impacts of gardening on cognitive measures of attention and executive functioning that may become apparent only after more prolonged periods of time (Hartig et al., 2003). By including cognitive measures along with psychological and physiological measures, future research may shed more light on the relative importance of 'attention restoration' and 'psycho-physiological stress recovery' as the two main processes that have been theoretically implicated in the restorative effects of nature (Hartig, 2007).

By providing the first evidence from controlled research for the restorative effects of gardening, the present study highlights the relevance of gardening as a valuable resource to disease prevention and health promotion. These insights have many potential implications for individuals, governments and healthcare organizations. For example, stressed garden owners may consider tending their own garden instead of hiring gardeners to do the work.

Governments and healthcare organizations may act upon the present findings by securing and perhaps even extending the space allocated to private and public gardens, which, in many countries, is under strong pressure from urban expansion and infill developments (Wiltshire & Azuma, 2000). More generally, studies of the restorative effects of gardening highlight the importance of the environment in promoting more healthy and sustainable lifestyles.

References

Armstrong, D. (2000). A survey of community gardens in upstate New York: Implications for health promotion and community development. *Health & Place*, *6*(4), 319–327.

Catanzaro, C., & Ekanem, E. (2004). Home gardeners value stress reduction and interaction with nature. *Acta Horticulturae*, *639*, 269–275.

Clayton, S. (2007). Domesticated nature: Motivations for gardening and perceptions of environmental impact. *Journal of Environmental Psychology*, *27*(3), 215–224.

Dunnett, N., & Qasim, M. (2000). Perceived benefits to human well-being of urban gardens. *HorTechnology*, *10*(1), 40–45.

Francis, M., & Hester, R. T. (1992). *The meaning of gardens*. Cambridge, MA: MIT Press.

Fries, E., Dettenborn, L., & Kirschbaum, C. (2009). The cortisol awakening response (CAR): Facts and future directions. *International Journal of Psychophysiology*, *72*(1), 67–73.

Gigliotti, C. M., Jarrott, S. E., & Yorgason, J. (2004). Harvesting health: Effects of three types of horticultural therapy activities for persons with dementia. *Dementia*, *3*(2), 161–180.

Gross, H., & Lane, N. (2007). Landscapes of the lifespan: Exploring accounts of own gardens and gardening. *Journal of Environmental Psychology*, *27*(3), 225–241.

Hansen, A. M., Garde, A. H., & Persson, R. (2008). Sources of biological and methodological variation in salivary cortisol and their impact on measurement among healthy adults: A review. *Scandinavian Journal of Clinical & Laboratory Investigation*, *68*(6), 448–458.

Hartig, T. (2007). Three steps to understanding restorative environments as health resources. In C. Ward Thompson & P. Travlou (Eds.), Open space: People space (pp. 163–179). London: Taylor & Francis.

Hartig, T., Evans, G. W., Jamner, L. D., Davis, D. S., & Garling, T. (2003). Tracking restoration in natural and urban field settings. *Journal of Environmental Psychology*, *23*(2), 109–123.

Hellhammer, D. H., Wust, S., & Kudielka, B. M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology*, *34*(2), 163–171.

Jeon, C. Y., Lokken, R. P., Hu, F. B., & van Dam, R. M. (2007). Physical activity of moderate intensity and risk of type 2 diabetes. *Diabetes Care*, *30*(3), 744–752.

Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. New York: Cambridge University Press.

Kirschbaum, C., & Hellhammer, D. H. (1994). Salivary cortisol in psychoneuroendocrine research: Recent developments and applications. *Psychoneuroendocrinology*, *19*(4), 313–333.

Lemaitre, R. N., Siscovick, D. S., Raghunathan, T. E., Weinmann, S., Arbogast, P., & Lin, D. Y. (1999). Leisure-time physical activity and the risk of primary cardiac arrest. *Archives of Internal Medicine*, *159*(7), 686–690.

Levine, T. R., & Hullett, C. R. (2002). Eta squared, partial eta squared, and misreporting of effect size in communication research. *Human Communication Research*, *28*(4), 612–625.

Maas, J., Verheij, R. A., de Vries, S., Spreeuwenberg, P., Schellevis, F. G., & Groenewegen, P. P. (2009). Morbidity is related to a green living environment. *Journal of Epidemiology and Community Health*, *63*(12), 967–973.

Macleod, C. M. (1991). Half a century of research on the Stroop effect: An integrative review. *Psychological Bulletin*, *109*(2), 163–203.

Milligan, C., Gatrell, A., & Bingley, A. (2004). 'Cultivating health': therapeutic landscapes and older people in northern England. *Social Science & Medicine*, *58*(9), 1781–1793.

Mitchell, R., & Popham, F. (2008). Effect of exposure to natural environment on health inequalities: An observational population study. *Lancet*, *372*(9650), 1655–1660.

Ottosson, J., & Grahn, P. (2005). A comparison of leisure time spent in a garden with leisure time spent indoors: On measures of restoration in residents in geriatric care. *Landscape Research*, *30*(1), 23–55.

Park, S. A., Shoemaker, C., & Haub, M. (2008). Can older gardeners meet the physical activity recommendation through gardening? *Horttechnology*, *18*(4), 639–643.

Rodiek, S. D. (2002). Influence of an outdoor garden on mood and stress in older persons. *Journal of Therapeutic Horticulture*, *13*, 13–21.

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: A unifying theory. *Clinical Psychology Review*, *21*(1), 33–61.

Simson, S. P., & Straus, M. (Eds.). (1998). *Horticulture as therapy: Principles and practices*. New York: Haworth Press.

Storch, M., Gaab, J., Kuttel, Y., Stussi, A. C., & Fend, H. (2007). Psychoneuroendocrine effects of resource-activating stress management training. *Health Psychology*, *26*(4), 456–463.

Teychenne, M., Ball, K., & Salmon, J. (2008). Physical activity and likelihood of depression in adults: A review. *Preventive Medicine*, *46*(5), 397–411.

Thompson, P. D., Crouse, S. F., Goodpaster, B., Kelley, D., Moyna, N., & Pescatello, L. (2001). The acute versus the chronic response to exercise. *Medicine and Science in Sports and Exercise*, *33*(6), S438–S445.

Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology*, *11*(3), 201–230.

Van Aken, M. O., Romijn, J. A., Miltenburg, J. A., & Lentjes, E. (2003). Automated measurement of salivary cortisol. *Clinical Chemistry*, *49*(8), 1408–1409.

Van den Berg, A. E., Hartig, T., & Staats, H. (2007). Preference for nature in urbanized societies: Stress, restoration, and the pursuit of sustainability. *Journal of Social Issues*, *63*(1), 79–96.

Van den Berg, A. E., Koole, S. L., & van der Wulp, N. Y. (2003). Environmental preference and restoration: (How) are they related? *Journal of Environmental Psychology*, *23*(2), 135–146.

Van den Berg, A. E., Maas, J., Verheij, R. A., & Groenewegen, P. P. (2010). Green space as a buffer between stressful life events and health. *Social Science & Medicine*, *70*, 1203–1210.

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect—the PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070.

Weyerer, S., & Kupfer, B. (1994). Physical exercise and psychological health. *Sports Medicine*, *17*(2), 108–116.

Wichrowski, M., Whiteson, J., Haas, F., Mola, A., & Rey, M. J. (2005). Effects of horticultural therapy on mood and heart rate in patients participating in an inpatient cardiopulmonary rehabilitation program. *Journal of Cardiopulmonary Rehabilitation and Prevention*, *25*(5), 270–274.

Wiltshire, R., & Azuma, R. (2000). Rewriting the plot: Sustaining allotments in the UK and Japan. *Local Environment*, *5*(2), 139–151.

Author biographies

AGNES E. VAN DEN BERG is an associate professor and senior researcher at Wageningen University and Research Center. Her main research interests are in environmental preferences and the health benefits of nature.

MARIËTTE H.G. CUSTERS completed this research for her thesis at Leiden University. Since graduation, she has participated in several projects at Wageningen University and Research Center.