Mathematical Formalization as a Means to Inform and Improve Connection to Nature Interventions

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Abstract

Connection to nature is an important driver of pro-environmental behavior. However, it remains unclear which strategies for fostering this connection are effective despite various studies testing diverse interventions. Mathematical formalization offers to be a promising yet underexplored method for examining how specific intervention components influence outcomes. We applied mathematical modeling to existing data on connection to nature interventions, focusing on the roles of intervention duration and the inclusion of a mindfulness component. Using data from two prior studies—one centered on intervention duration and the other on adding mindfulness—we developed several equations to investigate changes in connection to nature, expected outcomes, and the duration required to achieve significant improvements. These formalizations of the relationships investigated can be a basis for others investigating similar questions. The results indicate that contact with nature interventions may not be a feasible approach, as it would take nearly a month to reach higher levels of connection. In contrast, combining it with a mindfulness component has potential to drastically reduce the necessary duration of the intervention to reach similar outcomes to around a week. These findings demonstrate the potential of mathematical formalization as a means to clarify the mechanisms underlying intervention effectiveness and to guide the design of more efficient strategies.

Keywords: connection to nature, mathematical formalization, inclusion of nature in self, mindfulness

Introduction

Contact with and connection to nature are important drivers of pro-environmental behavior (Tam, 2013; Whitburn et al., 2020) and of well-being (Capaldi et al., 2015; Mayer & Frantz, 2004). However, despite the growing evidence of connection to nature's benefits, it seems to get out of the individual and societal focus (Kesebir & Kesebir, 2017). One explanation brought forth for this is that contemporary predominantly urban lives (Barlett, 2008; Vining et al., 2008) and increasing indoor entertainment alternatives (Kesebir & Kesebir, 2017) may result in a weakened human connection with nature.

The concept of connection to nature can be understood as an umbrella term for various emotional and cognitive components of humans perceiving themselves as part of or related to nature (Tam, 2013). Related concepts include, for example, inclusion of nature in self (Schultz, 2001), connectedness to nature (Mayer & Frantz, 2004), and emotional affinity toward nature (Kals et al., 1999; Tam, 2013). Even though there are some differences between the aforementioned concepts and other related concepts not listed here, a study by Tam (2013) with a selection of measures of connection to nature showed convergent validity, which supports the notion of a shared underlying construct like connection to nature. Research has found several antecedents of connection to nature including experiences with nature, interindividual differences and psychological states (Lengieza & Swim, 2021). However, the interventions aimed at reestablishing or inducing connection to nature developed in different disciplines have been insufficiently compared to each other (Tam, 2013). The evidence of the intervention‘s effectiveness is often based on the significance of a comparison between two or more conditions or points in time (e.g., Braun & Dierkes, 2017; Nisbet et al., 2019; Sellmann & Bogner, 2013). A problem with this method is that it only provides limited information to evaluate which interventions are better suited to improve connection based on the practical relevance of their effects. This can be

illustrated with the following example. In their results section Braun and Dierkes (2017) wrote the following:

> The comparison of INS [Inclusion of Nature in Self scale] scores between pre- (T1) and post-test (T2) through Friedman test revealed *highly significant increases* [emphasis added] in connectedness to nature within both experimental subgroups ($p < .001$). The *effect sizes though were relatively small* [emphasis added] (5-days, Cohen's $d = .261$; 1-day, Cohen's $d = .212$). (p. 941)

While the difference between pre- and post-test indicates a statistically significant change, the effect sizes are only briefly mentioned and interpreted as relatively small, which indicates they might not be practically relevant. However, in their discussion the authors come to the following conclusion without further discussion of the effect sizes or implications for the practical relevance of the effects found:

> After participating in the outdoor environmental intervention both experimental groups revealed a significantly stronger connection to nature than prior to the intervention. … This finding *proves the efficacy* [emphasis added] of outdoor environmental education programs when it comes to strengthening students' connectedness with nature. (Braun & Dierkes, 2017, pp. 943–944)

It is clear that the intervention done by the authors does change connection to nature, but it remains unclear whether what they interpret as small changes is practically relevant and thus whether the intervention is a useful tool to foster connection to nature and a pathway to its benefits. To evaluate whether the intervention indeed has efficacy as the authors claim, a clear reference and interpretation of the effects is needed (Funder & Ozer, 2019). In the debate about effect sizes and their use for evaluating the practical relevance of effects found, several approaches have been proposed to make the interpretation of effects more meaningful. These include comparisons with benchmarks like well-

established psychological findings or with intuitively understood non-psychological relations and considering the consequences of an effect in the long run (Funder & Ozer, 2019).

Studies like the one by Braun and Dierkes (2017) presented earlier have the issue of remaining ambiguity due to them insufficiently exploring practical relevance. Due to the problems associated with effect sizes and their interpretation, relying on them has limited potential to resolve these ambiguities. Another approach that increases clarity is needed. Mathematical formalization has been one way to understand and describe scientific approaches, findings, and relations in the world since the time of the ancient philosophers (Suppes, 1968). To do this formalization does not rely on vague and sometimes arbitrarily set interpretations of effect sizes (Funder & Ozer, 2019). It has promise to increase clarity by systematically breaking down the observed changes as objectively as possible, and by clearly stating both the underlying assumptions and the resulting findings (Suppes, 1968). This thesis explores this approach to examine the practical relevance of effects that does not rely solely on effect sizes. The focus lies on investigating connection to nature interventions and their effects by conducting secondary analysis of pre-existing studies. The goals of this thesis are to further investigate connection to nature interventions and how to improve them, and to test mathematical formalization as a tool for it. This leads to the following research questions: How can a formalized mathematical model be used to inform predictions of connection to nature after an intervention? And how can connection to nature interventions be improved based on such models? To investigate these questions, I will apply mathematical equations to the data of two pre-existing studies that tested different aspects of interventions aimed at enhancing connection to nature. The respective studies and the investigated intervention aspects will be introduced in the respective parts of this thesis.

Part 1 - Duration: How Effective is Contact With Nature for Multiple Days?

One of the dimensions on which interventions differ and potentially a factor influencing their effectiveness is their length, often the duration of exposure to nature. It has been pointed out previously

to be a relevant dimension to investigate in future research (e.g., Mayer et al., 2009). There is only limited research explicitly investigating the duration of the intervention. In research on connections to nature, duration is often only examined in conjunction with other variables, but it is rarely explicitly manipulated in experimental designs (e.g., Barton et al., 2016). While some studies identify differences for varying durations (e.g., Barton & Pretty, 2010; Wyles et al., 2019), others find limited to no support (e.g., Barton et al., 2016; Bolouki et al., 2025). Changing or adapting the duration of nature or virtual nature-based interventions is, however, still discussed as an influence on interventions effectiveness (e.g., Coughlan et al., 2022).

Basis of Data

A study by Braun and Dierkes (2017) investigated the effects of an outdoor environmental education program on school students' nature connectedness in a quasi-experimental design. Part of their study was the comparison of a 5-day residential environmental program (n = 194) and a 1-day outdoor educational program (n = 182). To measure connection to nature, the authors used the Inclusion of Nature in Self scale (INS; Schultz, 2001), a single-item scale with seven variations of overlapping circle pairs labelled 'nature' and 'me'. The INS was applied together with a questionnaire containing further questions two weeks prior to the intervention, directly following it, and six weeks thereafter. Despite the contents of the two experimental groups having the same theme "nature and species conservation in your environment – think global, act local" (Braun & Dierkes, 2017, p. 941), there were some differences. The 5-day group stayed at a resort and made multiple field trips into the rainforest, while the 1-day group only participated in one full-day field trip into the rainforest.

General effects of Visiting Days and Follow-Up Days

Visiting Days

Overall, Braun and Dierkes (2017) concluded that a more intense 5-day intervention (Cohen's d = 0.261; p. 941) was more effective than the 1-day variation (Cohen's d = 0.221; p. 941). This section

explores what changing the duration of an intervention does to its overall effects, building on the differences found between medians before and after the interventions and the follow-up-measure.

For the purposes of this thesis, it is assumed that the initial day of the 5-day intervention led to a similar change as the 1-day intervention. Furthermore, the remaining effect of the 5-day intervention will be assumed to be stable and equally attributable to the remaining four days, respectively. The original separate interventions will be further understood as one intervention, but with different lengths, to further investigate the influence of its duration on the intervention's effect.

To understand how the duration of an intervention influences its overall effect, it is essential to determine the overall effect itself. These effects can be calculated based on an equation. Based on the assumptions made previously, there is an effect of the first day (b_{day1}), and an effect of the subsequent days (b_{dayx}), which add together to the overall change in connection to nature (Δc). To account for different durations, the effect of the following days can be multiplied by the remaining number of days after subtracting 1 for the first day, whose effect is already represented by b_{day1}, Leading to

$$\Delta c = b_{day1} + b_{dayx}(d - 1), \quad (1)$$

Here Δc is the overall change in connection to nature, b_{day1} is the effect of the first day, b_{dayx} is the effect of the following days, and $d - 1$ represents the number of following days based on the overall number of intervention days d for cases $d \in \mathbb{N}$. Unless otherwise specified, all variables here and in following equations are assumed to take values in $\mathbb{R}$ within boundaries like scale limits. The symbols used are described in Table 1.

Descriptions under new equations in this thesis will contain a short explanation of newly introduced variables and parameters, a reference to earlier equations they are based on and a reference to Table 1, which contains an overview of all symbols including the equations they are used in, to avoid repetition of explanations of recurring variables. Unless otherwise specified, all variables here and in following equations are assumed to take values in $\mathbb{R}$ within boundaries like scale limits. Explanations will

not be repeated under equations if they are equations mentioned earlier in which specific values have been inserted to do a calculation. Inserted values will be highlighted in bold.

Table 1

Description of the Used Symbols and Equations They are Used in

	Variable	Equations
Δc	Change in connection to nature in units of the INS scale	1, 2
d	Overall number of intervention days	1, 2, 3, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21
b_{day1}	Effect of the intervention on the first day	1, 3, 7, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21
b_{dayx}	Effect of the intervention on each of the following days	1, 3, 7, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21
c_a	Connection to nature in units of the INS scale after the intervention	(*1*)3, 4, 5, 6, 7, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21(*1*)
c_b	Connection to nature in units of the INS scale before the intervention	3,7, 9, 10, 11, 12, 13, 14, 15, 17, 18, 19, 21
i	Indicator whether an intervention was used (1) or not (0)	3, 9, 10, 11
b_{MDay1}	Added effect on the first day of combining the intervention with mindfulness	9
b_{MDayx}	Added effect on each of the following days of combining the intervention with mindfulness	9
m	Indicator for whether there was a mindfulness component (1) or not (0)	9, 10, 11
Δm	Change in mindfulness in units of the TMS scale	17, 18, 19, 21, 22
b_m	Factor with which a change in mindfulness translates into a change of the overall effect of the intervention	17, 18, 19, 21

Note. Further information about notation under equations can be found under Equation 1 on page 8.

Actual evidence from by Braun and Dierkes (2017) was be used to specify the model. In the study there was an improvement of 0.32 units on the INS scale on the first day found for the 1-day group (see

Table 2). The four following days showed an overall increase of 0.12 units. Assuming a constant linear change per day, this equates to 0.03 units of change per day after the first day. This implies that the first day has over ten times as much of an effect as the subsequent days. To calculate the change in connection to nature (Δc) for an intervention lasting a specific number of days, $b_{day1} = 0.32$ and $b_{dayx} = 0.03$ can be inserted in Equation 1, resulting in

$$\Delta c = 0.32 + 0.03(d - 1), \quad (2)$$

The terms used here are explained under Equation 1 and symbols are described in Table 1.

Based on Equation 2 the overall change in connection to nature can now be calculated for the study. Simply quantifying the change has limited informational value. However, in most interventions this is not the question. Often there is an idea that something needs to be improved but the question is, which intervention can be used and what level of the target outcome can be reached with it. It is therefore useful to ascertain which level of connection to nature can be achieved with an intervention. For this it is necessary to be able to predict the connection after the intervention based on the parameters of the intervention and an initial value. To be able to predict connection to nature in units of the INS scale after an intervention (c_a) the following parameters and variables were inserted into a linear regression equation, like $\hat{y} = \beta_0 + \beta_1 x_1 + \beta_2 x_2$: Connection to nature before the intervention (c_b) and based on Equation 1 $b_{day1} + b_{dayx}(d - 1)$ for the effects added to it. A factor i is introduced to account for whether an intervention was applied ($i = 1$), with the effects being added, or not ($i = 0$), with the effects not being added, making $i \in \{0,1\}$. Both effects will be multiplied by i to apply them or not respectively. This results in

$$c_a = c_b + b_{day1} i + b_{dayx}(d - 1)i. \quad (3)$$

Here, c_a is the value in connection to nature after the intervention whereas c_b refers to the initial value. i is a factor to account for cases with and without an intervention. The other terms are explained under Equation 1 with the difference that here $d \in \mathbb{N}_0$. Symbols are described in Table 1. A

linear relationship is chosen here, as it is the basic relationship often assumed in psychology (Cohen & Cohen, 1983). Of course, this is an assumption made for an initial approach, and other types of relationships would be possible. However, developing models for other relationships would require different types of data from multiple points in time.

Table 2

Median Values from the Original Intervention Study for the Three Measurements

Measurement point	Median on INS scale	
	1-day intervention (*n* = 182)	5-day intervention (*n* = 194)
Before (B)	3.94	3.82
After 1 day (A1)	4.26	-
After 5 days (A5)	-	4.26
Follow-up (F)	4.80	4.69
Difference A1 - B	0.32[a]	-
Difference A5 - B	-	0.44 [a]
Difference F-A1	0.54 [a]	-
Difference F-A5	-	0.43[a]

Note. Values taken from Table 2 in "Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs," by T. Braun and P. Dierkes, 2017, *Environmental Education Research, 23(7),* p. 942.

[a] Values calculated based on the original values.

To be able to investigate the implications further applied to a concrete intervention, values found in the study by Braun and Dierkes (2017) were inserted into Equation 3 - specifically, the median

of connection to nature of the 1-day group (3.94) as the value of connection before the intervention ($c_b = 3.94$) and the effect values based on Equation 2 resulting in

$$c_a = 3.94 + 0.32i + 0.32(d-1)i. \quad (4)$$

The terms used are explained under Equation 3, except the inserted values for the effects which are explained under Equation 2. The symbols are defined in Table 1.

To better understand the implications of different cases, these can now be inserted into Equation 4 . For the case of no intervention being applied, *i* = 0 and d = 0 are inserted, leading to

$$c_a = 3.94 + 0.32 * \mathbf{0} + 0.03 * (\mathbf{0} - 1) * \mathbf{0} = 3.94. \quad (5)$$

For all cases in which an intervention takes place, i is set to $i = 1$ and the number of intervention days is inserted for d. For an intervention lasting five days, the result is:

$$c_a = 3.94 + 0.32 * \mathbf{1} + 0.03 * (\mathbf{5} - 1) * \mathbf{1} = 4.38. \quad (6)$$

This is what the actual data from Braun and Dierkes (2017) shows, except for the deviation due to the different initial values of the groups in the study. Which implies that the model fits the data. While this enables predictions for scenarios based on variations of duration, effects, and starting value, another relevant question for practitioners is: How long does it take to reach a specific value, as a goal and sometimes even the intervention is known, but not how long it should be applied. In order to predict this, Equation 3 was rearranged and adapted. As calculating a duration is only sensible for cases in which there is an intervention, *i* can be left out. Solving for *number of days* then, yields*:*

$$d = \frac{c_a - c_b - b_{day1}}{b_{dayx}} + 1 \quad (7)$$

for $d > 0$. Into this equation a goal value for c_a and for c_b, the value the target group has before the intervention, can be inserted. I set the goal of participants reaching a higher level of connection to nature. On the INS this would correspond to five, where there is more overlap between the circles of 'me' and 'nature' than non-overlap. Inserting the values found for the sample ($c_b = 3.94$; $b_{day1} =$

$0.32;\ b_{dayx} = 0.03$) in the study by Braun and Dierkes (2017) and the goal of $c_a = 5$ into Equation 7, results in

$$d = \frac{\mathbf{5 - 3.94 - 0.32}}{\mathbf{0.03}} + 1 = 25.66. \quad (8)$$

This would mean that a minimum of 26 days of excursions into the rainforest or similar interventions would be needed to get the participants from the study to be more connected to nature than not. If another type of relationship were assumed instead of a linear one, where the effect would get smaller every day, the number of days needed would be even higher.

Follow-Up Days

The study by Braun and Dierkes (2017) also found notable changes between the post-intervention and follow-up measurements. For the 1-day intervention, the difference between the follow-up measurement six weeks after the intervention (4.80) and the immediate post-intervention value (4.26) of connection to nature was 0.54. This difference is slightly larger than the corresponding change observed in the 5-day intervention, where the follow-up value (4.69) was 0.43 higher than the post-intervention value (4.26).

Both differences are close to or even bigger than the change due to the intervention itself (see Table 2). However, these relatively large changes diminish in relation to the time in which they were reached. For the 1-day intervention a change of 0.54 was found, but this only amounts to an average change of 0.013 per day for the six weeks between the post-measure and the follow-up measure. This makes even the subsequent days after the first, more effective day of the intervention over 2.3-times more effective than individual follow-up days. For the 5-day intervention the difference in effect was even bigger. Here, the effect per follow-up day is only 0.010 making the intervention days three or more times as effective as the days after the intervention. As these effects are smaller than those of intervention days, they will not be investigated further here, but they might still have a relevance and enhance effects of interventions in the long run. There is a small difference between the effectiveness of

the follow-up days of the 1-day and the 5-day intervention. Unfortunately, based on the given data, it is not possible to definitively determine whether the observed difference is due to variations between intervention groups, measurement discrepancies, or actual effects from the length of the intervention.

Discussion of the General Effects of Visiting Days and Follow-Up Days

According to the considerations and calculations made based on the data from Braun and Dierkes (2017), the largest effect occurs on the first intervention day. Even though the first day alone produces an effect that is more than ten times greater than those that follow, subsequent days continue to build on this initial effect. This suggests that extending the intervention may still enhance its outcomes. Thus, prolonging the intervention might be a way to increase the effect of the intervention.

Based on the developed equation predictions can be made about the duration such interventions require to increase connection to nature to a specific level. These interventions need to be too long to be practically feasible. Based on the results, reaching higher levels of nature connection will require interventions lasting 26 days or more, which would not be feasible for most contexts. Taking follow-up days into account, the duration of interventions might be reduced, but uncertainties regarding the follow-up days effectiveness remain. Based on the available data some simplifying assumptions were made, like stable effects or further intervention days and follow-up days. Therefore, the real duration might differ. For example, with a decline of the effect for each day interventions would become even longer or never reach the goal value. The lower effectiveness in follow-up days for the 5-day as opposed to the 1-day intervention could also be interpreted as indication of a limit to what nature connection values can be reached with these interventions or in general. Both, lowering effects and limits to reachable connection to nature remain, however, speculation as the data given does not give a clear indication of the reason for these differences.

Given that the first intervention day has more effect than the following days of a contact with nature intervention and intervention days are generally more effective than follow-up days, it seems worthwhile to explore alternatives to simply prolonging the intervention.

This is especially relevant considering the impracticality of taking individuals into nature for nearly a month to induce a higher level of connection to nature. One potential alternative could be to combine multiple shorter interventions, leveraging the disproportionately high impact of the first day multiple times. However, to meaningfully evaluate this approach, specific data on repeated short-term interventions within the same sample would be required. Alternatively, contact to nature could be complemented or strengthened by other factors to increase the overall effects and thus reduce the duration of the intervention. There are other antecedents of connection to nature (Lengieza & Swim, 2021). A factor that has proven to be an antecedent of connection to nature as well as useful for increased effects of contact to nature interventions is mindfulness (Lengieza & Swim, 2021; Nisbet et al., 2019). Integrating mindfulness into the intervention design may, therefore, represent a promising strategy to boost outcomes while keeping interventions manageable in duration.

Part 2: Mindfulness

Mindfulness is about conscious awareness and active attention to one's experiences in the present moment in time (Brown & Ryan, 2003) and aims at increasing people's focus on their current experience (van Dam et al., 2018). Across several studies a significant positive relationship between connection to nature and mindfulness of $r = .25$ with $p < .001$ could be shown (Schutte & Malouff, 2018), implicating mindful contact with nature being associated with increased connection. The mindful focus on the moment is assumed to increase the ability to connect with and experience nature in interventions (Lengieza & Swim, 2021) and experience its benefits more efficiently (Nisbet et al., 2019). The understanding of which facets of mindfulness drive this influence and the general process of mindfulness

increasing connection to nature is, however, still limited (Lengieza & Swim, 2021). Its potential to strengthen the effects of contact to nature interventions will be probed in the following.

Basis of data

Nisbet et al. (2019) investigated the added value of mindfulness in an intervention aimed at strengthening connection to nature. This thesis will use data taken from this study to conduct secondary analysis in the following part. They investigated whether adding mindfulness to a brief contact with nature intervention would enhance its effects on nature connection and mood in an experimental study with university students. The study compared three conditions: indoor (n = 31), where participants walked indoors; outdoor (n = 35), where participants walked outside and outdoor-mindfulness (n = 34), in which participants walked outdoors while following a 20-minute mindfulness exercise. As a measure for state connection to nature this study also used the inclusion of Nature in Self scale (Schultz, 2001) and for state mindfulness the 13-item state Toronto Mindfulness Scale (TMS; Lau et al., 2006) was employed. The TMS contains two subscales one focused on participants' level of curiosity in the moment and the other on their level of decentering, which is about experiencing one's thoughts and feelings with some distance and disidentification, in a Likert response format, ranging from 1 (not at all) to 5 (very much; Lau et al., 2006).

Before the respective walk of their condition participants filled out a questionnaire, which contained questions not referenced further in this thesis. After the walk the participants were given a post-walk questionnaire indoors or outdoors respectively. This questionnaire included the measures of connection to nature and state mindfulness of which the results are used in this thesis and further measures. After the walk and the post-walk questionnaire participants took part in another task for another study. Further details regarding other variables measured and tasks performed in the original study can be found in the paper by Nisbet et al. (2019).

Additional Effects of Mindfulness

Overall Nisbet et al. (2019) concluded that those in the outdoor-mindfulness condition had substantially higher values in connection to nature than those in the outdoor condition, who had significantly higher values than those in the indoor condition. From the data gathered in the study, the reported means and standard deviations from the post walk questionnaire will be used for this thesis (see Table 3).

The higher effects for the outdoor-mindfulness condition compared to the outdoor condition, indicate that there is an additional effect from adding mindfulness to the intervention. Assuming that having an additional mindfulness component leads to additional effects, one can extend Equation 3 with terms for these added effects of mindfulness in the combined condition like those used for the intervention effects in Equation 1: b_{MDay1} for the effect of the first day; b_{MDayx} for the effects of the following days, which are also multiplied by the number of following days $d-1$; and similar to i an indication m, whether a mindfulness component was used ($m=1$) or not ($m=0$), making $m \in \{0,1\}$. This results in the piecewise function

$$c_a = \begin{cases} c_b + b_{day1}i + b_{dayx}(d-1)i + b_{MDay1}m + b_{MDayx}(d-1)m, & for \neg(m=1 \wedge i=0) \\ undefined, & for\ (m=1 \wedge i=0). \end{cases} \quad (9)$$

Here b_{MDay1} is the additional mindfulness effect of the first day, b_{MDayx} the additional mindfulness effect of the following days and m an indication whether an additional mindfulness component is used in the intervention. The other terms are explained under Equation 3 and symbols are described in Table 1. While the effects of mindfulness are being represented here simplified by addition, they are not to be understood as separate main effects of mindfulness, but rather the overall combined additional effects of mindfulness and the interaction of it with the effects of the original intervention. As there is no data for a separate only mindfulness condition assumptions main effects of mindfulness and possible interactions with the intervention cannot be differentiated to be represented independently.

Table 3

Mean Values from the Brief Contact to Nature Intervention Study for the Three Conditions.

Variable	Condition		
	Indoor	Outdoor	Outdoor-mindfulness
	M (*SD*)	*M* (*SD*)	*M* (*SD*)
State mindfulness	2.77_{a} (0.64)	2.86_{ab} (0.71)	3.22_{b} (0.65)
State connection to nature	2.58_{a} (1.18)	3.38_{b} (1.26)	4.18_{c} (1.13)
Difference to indoor group in connection to nature	-	0.8[a]	1.6[a]

Note. Means in the same row that do not share subscripts differ significantly at $p < .05$ based on Tukey HSD post hoc comparisons made in the original study. Values and subscripts taken from Table 2 in "Mindfulness in Nature Enhances Connectedness and Mood," by E. K. Nisbet, J. M. Zelenski and Z. Grandpierre, 2019, *Ecopsychology, 11(2),* p. 86.

[a] Values calculated based on the original values

To be able to better understand how adding a mindfulness component changes the effects, data from the study will be used for calculations. As the data set does not contain before values or ones for the change from before to after the intervention the indoor condition is used as an approximation for the initial value without a nature contact intervention. The difference between the after value in connection to nature in the outdoor condition and the indoor condition found was 0.8 and that between the outdoor-mindfulness condition and the indoor condition 1.6 (see Table 3). Comparing these differences indicates that the additional change in the outdoor-mindfulness condition, beyond what is contributed by the outdoor intervention alone is equal to the increment of 0.8 added by the outdoor

condition alone. Under the assumption that this means the effects of the intervention and the added effects being the same, b_{MDay1}= b_{day1} and b_{Mdayx} = b_{dayx} can be inserted into Equation 9 resulting in

$$c_a = c_b + b_{day1}i + b_{dayx}(d-1)i + b_{day1}m + b_{dayx}(d-1)m \quad (10)$$

By factoring out the common term $b_{day1} + b_{dayx}(d-1)$ and then grouping i and m this equation can be simplified into

$$c_a = c_b + (b_{day1} + b_{dayx}(d-1))(i+m). \quad (11)$$

This equation allows calculation of connection to nature after contact to nature interventions similarly to Equation 3. The additional last bracket $(i+m)$ allows to consider additional cases,

a) the case of no intervention taking place (i = 0, $m = 0$), results in only the initial value being kept,

$$c_a = c_b + (b_{day1} + b_{dayx}(d-1))\,(\mathbf{0} + \mathbf{0}) = c_b \quad (12)$$

b) the case of an intervention (i = 1) without mindfulness ($m = 0$) taking place, results in $c_a = c_b + (b_{day1} + b_{dayx}(d-1))\,(\mathbf{1} + \mathbf{0})$, which simplifies into Equation 3, the equation for interventions without a mindfulness component.

c) and the case of an intervention (i = 1) with a mindfulness component ($m = 1$) results in,

$$c_a = c_b + (b_{day1} + b_{dayx}(d-1))(\mathbf{1} + \mathbf{1})$$
$$c_a = c_b + 2(b_{day1}\mathbf{1} + b_{dayx}(d-1)), \quad (13)$$

so, the combined effects being doubled.

Doubled effects promise a potential substantial reduction of the needed duration of the intervention. To be able to investigate this reduction an equation calculating the number of days needed to reach a certain value of connection to nature is needed, which takes the additional mindfulness component into account. Solving Equation 14 for *number of days,* results in

$$d = \frac{\frac{c_a - c_b}{2} - b_{Day1}}{b_{Dayx}} + 1 \quad (14)$$

Applying in the data from the study ($c_b = 3.94;\ b_{day1} = 0.32;\ b_{dayx} = 0.03$) to reach $c_a = 5$ similar as in Equation 8(*8*) in Part 1, results in

$$d = \frac{\frac{\mathbf{5 - 3.94}}{2} - \mathbf{0.32}}{\mathbf{0.03}} + 1 = 8 \quad (15)$$

This indicates that an intervention including additional mindfulness components can reduce the number of interventions days needed drastically, to only eight days if the assumption of linear effects and mindfulness doubling the effects hold up. This would make for a much shorter and thus potentially more feasible intervention.

Discussion of Additional Effects of Mindfulness

Based on the developed equations expanding the intervention with mindfulness components has an added benefit. These additional effects can potentially reduce the time needed to reach a higher value in connection to nature drastically, indicating that adding mindfulness can substantially improve contact to nature interventions. However, these drastic changes are built on a model that makes considerable assumptions based on the data available. Firstly, a rather static effect of simply double the effects is assumed. Many relationships found in psychology are, however, dynamic and rely on the value of the related variables. Secondly, based on the data available a differentiation between main and interaction effects of mindfulness was not possible. Depending on their respective influence, such a differentiation is relevant to understanding how to most effectively add mindfulness to contact to nature interventions. On the one hand if the main effect is more impactful, one could have separate mindfulness and contact to nature components or even interventions. On the other hand, if the main drivers of these additional effects are interactions, an interwoven combination of contact to nature and mindfulness components in one intervention would be more promising. To definitively determine the relationship between contact to nature and mindfulness models based on more specific research and

data would be needed. However, it is still possible to conclude that adding mindfulness to contact to nature interventions can improve them and potentially substantially reduces the length of interventions to reach certain levels of connection to nature.

The static relationship assumed in this part might be too much of a simplification, as relationships between mindfulness and connection to nature are often assumed to be dynamic (e.g., Schutte & Malouff, 2018; Unsworth et al., 2016). The study by Nisbet et al. (2019), also shows differences in mindfulness between the conditions, indicating that not only connection to nature changed but also mindfulness. A change in mindfulness indicates that assuming simply having a mindfulness component will always double the effects compared to only contact to nature is not adequate. If the change in mindfulness potentially varies, its influence on the change in connection to nature will probably do so as well. Therefore, the effects of the intervention should also be related to the change in mindfulness in a dynamic relationship.

Part 3: Dynamic Mindfulness

To model a dynamic relationship that considers the change in mindfulness as a factor influencing how adding a mindfulness component influences change in connection to nature, Equations 3 and 11 can be combined as a basis. Equation 3 which models interventions without mindfulness applies for cases that do not have a change in mindfulness either due to no mindfulness components being added or them not having an effect. For cases with a change in mindfulness, an expanded equation is needed. Here Equation 10 can be considered as a starting point, as it contains effects for the intervention and effects of the added mindfulness component. However, it needs to be adapted to account for the relationship between change in mindfulness and that in connection to nature in a dynamic way. For the dynamic relationship, a multiplicative relationship between the effects of the intervention $b_{day1} + b_{dayx}$ $(d-1)$ and the change in mindfulness Δm is assumed. To further account for the strength of this effect a constant b_m is added to the equation. It represents how a change of one unit in mindfulness translates

into a change in the overall effect of the intervention, accounting for such relationships often not being strictly 1:1 (Cohen & Cohen, 1983). As the data of the studies used does not include information on negative changes in mindfulness and it is generally anticipated that mindfulness improves through interventions with a mindfulness component, there is no basis to model scenarios with negative changes. Based on these considerations the following function for all interventions that have no, or a (positive) change in mindfulness can be created by combining both equations into:

$$c_a = c_b + b_{day1} + b_{dayx}(d-1) + b_m\left(b_{day1} + b_{dayx} * (d-1)\right)\Delta m. \quad (16)$$

Here Δm represents the change in mindfulness due to the intervention and b_m represents the factor of conversion between this change and the change in the effects. The other terms used are explained under Equation 3 and Equation 10 and symbols are described in Table 1.[1]

Equation 17 can be simplified into

$$c_a = c_b + b_m\left(b_{day1} + b_{dayx}(d-1)\right)\left(\frac{1}{b_m} + \Delta m\right) \quad (17)$$

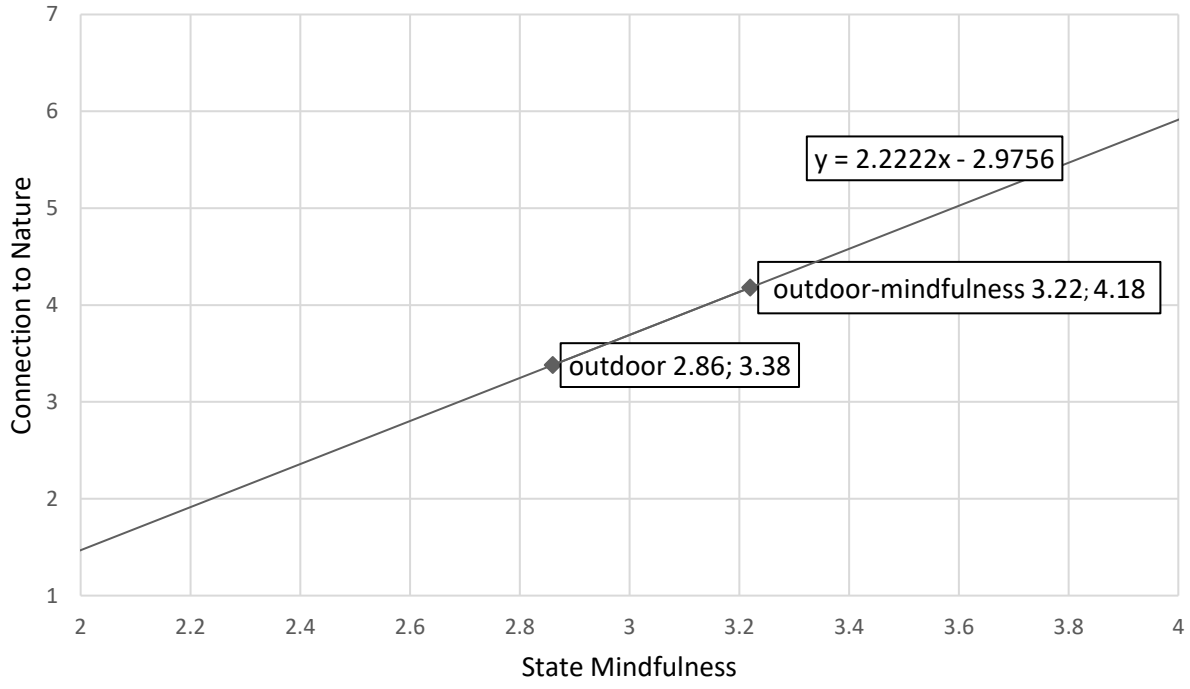
To apply this equation with the data from both studies, it is necessary to approximate the newly added factors. First, it is necessary to investigate how the conversion of changes in mindfulness is conversed into changes in the effects. Data from Nisbet et al. (2019) was used to approximate the factor b_m representing this conversion. Then, points (mindfulness|connection to nature) were derived to approximate a slope between mindfulness and connection to nature. Based on the points (2.86|3.38) for the outdoor (3.22|4.18) and for the outdoor-mindfulness condition a slope of 2.22 was calculated and plotted using Microsoft Excel (Microsoft Corporation; cf. Figure 1). Second, Δm needs to be

[1] The presentation and a preliminary version of this thesis included another formula here that lead to the conclusion that there might be a minimum change of Δm = 0.45 needed to improve interventions. Details can be found in the Appendix.

approximated. The difference in state mindfulness between the outdoor and outdoor-mindfulness condition in Nisbet et al. (2019) was 0.36 (cf. Table 3) and will be assumed as an approximation of the change in mindfulness due to adding mindfulness components in an intervention.

Figure 1

Regression slope for connection to nature plotted by state mindfulness for the outdoor and outdoor-mindfulness group



Note. Based on data from Table 2 in "Mindfulness in Nature Enhances Connectedness and Mood," by E. K. Nisbet, J. M. Zelenski and Z. Grandpierre, 2019, *Ecopsychology, 11(2),* p. 86.

To compare the effects found in this model with the previous ones, Equation 18 was rearranged to be able to calculate the days needed resulting in

$$d = \frac{\frac{c_a - c_b}{b_m\left(\frac{1}{b_m} + \Delta m\right)} - b_{day1} + b_{dayx}}{b_{dayx}} \quad (18)$$

Inserting the data used in previous parts ($c_b = 3.94$; $b_{day1} = 0.32$; $b_{dayx} = 0.03$; $c_a = 5$) and the approximation for change in mindfulness ($\Delta m = 0.36$) and the change factor ($b_m = 2.22$) into this equation leads to

$$d = \frac{\frac{\mathbf{5 - 3.94}}{\mathbf{2.22}\left(\frac{1}{\mathbf{2.22}} + \mathbf{0.36}\right)} - \mathbf{0.32} + \mathbf{0.03}}{\mathbf{0.03}} = 9.97 \quad (19)$$

This indicates that adding mindfulness instructions to a contact to nature intervention can indeed be a valuable addition to strengthen the intervention's effects.

To better understand the influence of mindfulness on the effectiveness of interventions, different scenarios with different values for the change in mindfulness were compared based on the studies' data. Other scenarios were inserted into Equation 19 like in Equation 20 to get a better understanding of the influence of the change in mindfulness. As comparison scenarios a low change scenario with half of the change found in the study ($\Delta m = 0.18$), a higher change scenario with one and a half times this change ($\Delta m = 0.54$) and a high change condition with double this change ($\Delta m = 0.72$) were used (see Table 4 for detailed results). Compared to the 26 days found in Part 1, all scenarios showed an improvement with the higher scenario resulting in under one week of intervention. The next question practitioners might ask is which change in mindfulness is needed to reduce the duration of the intervention down to a specific number of days.

Table 4

Different changes in mindfulness and their required intervention duration to reach higher connection to nature

Case	Change in mindfulness (Δm)	Duration in days to 5 on the INS scale (connection to nature)
no mindfulness – Part 1	**0.00**	**25.66**
1 (low)	0.18	15.58
2 (average) - Nisbet et al. (2018)	0.36	9.97
3 (higher)	0.54	6.40
4 (high)	0.72	3.93
Similar to Part 2	0.90	8

To be able to calculate the needed change in mindfulness for a specific number of days, Equation 18 was rearranged to calculate Δm into

$$\Delta m = \frac{c_a - c_b}{b_m(b_{\text{day1}} + b_{\text{dayx}}(d-1))} - \frac{1}{b_m} \quad (20)$$

Based on this Equation 21 it can be calculated how much change in mindfulness would be needed to reduce the duration of the intervention to reach the eight days calculated in Part 2 in Equation 16 by inserting d = 8 in Equation 21, resulting in

$$\Delta m = \frac{\mathbf{5 - 3.94}}{\mathbf{2.22\left(0.32 + 0.03(8-1)\right)}} - \frac{1}{\mathbf{2.22}} = 0.45 \quad (21)$$

This indicates that a 1.25-times larger change in mindfulness over the intervention would be needed than the one found in Nisbet et al. (2019) to reduce the duration of the intervention to the eight days found in Part 2.

Discussion of Effects of Dynamic Mindfulness

In this part additional equations to calculate the potential values after an intervention considering a dynamic relationship between the added mindfulness component and the change in connection to nature were developed. These can and were used to calculate the potential reduction in intervention duration for different changes in mindfulness. The results indicate that even small changes in mindfulness can substantially reduce the duration of an intervention. To reach the eight days determined in Part 2 a 1.25-times greater change in mindfulness than that found in the study by Nisbet et al. (2019) would be needed. As was also the case for the previous parts, these numerical results and the equations are based on a set of assumptions made based on limited data. To determine whether these assumptions hold up and to more precisely determine the influence of changes in mindfulness between different types of interventions, dedicated research and more and specific data is needed.

These results must be interpreted and used with caution as two data sets from different studies with different samples and types of interventions were used to develop the equations and do the calculations. One study used a sample of school students and a long-term intervention (Braun & Dierkes, 2017) and the other university students and brief contact to nature interventions (Nisbet et al., 2019). This potentially caused compatibility issues in the data and effects, that could have led to inconsistencies in the overall equation composition. Based on the equations developed here, future research can create more data, to more accurately describe the connection between mindfulness and connection to nature.

General Discussion

The purpose of this thesis was to further investigate whether mathematical formalization is suited to inform and improve connection to nature interventions. The developed equations and results

indicate that mathematical formalization based on existing data can be helpful. I was able to develop equations to predict potential outcomes for different types of interventions. Equation 3 does this for contact to nature interventions without an added mindfulness component. For interventions with a mindfulness component Equation 9 and 10 do the same under the assumption of a static relationship between mindfulness and connection to nature and Equations 17 and 18 for a dynamic relationship between the two. Additionally, I developed equations to calculate the duration of the interventions in days for interventions without a mindfulness component, Equation 7, and those with a mindfulness component for a static, Equation 15 (*14*), and a dynamic relationship between mindfulness and connection to nature, Equation 19. These equations can be utilized to make inferences about the practical relevance of various interventions for different sets of data and approaches.

For the applications based in the previous studies by Braun and Dierkes (2017) and Nisbet et al. (2019), the results indicate that, while there are changes in connection to nature due to contact with nature, these changes might not translate into a practically feasible intervention. For the rainforest excursion intervention by Braun and Dierkes (2017) results indicate that nearly a month of going into the rainforest might be needed to reach a higher level of connection to nature, which would make for an unfeasible intervention in most cases. Pure contact with nature seems therefore not enough to increase connection to nature which contradicts the claims made in the original study that their results would prove the efficacy of outdoor environmental education programs for strengthening students' connection with nature (Braun & Dierkes, 2017). The results based on data and insights from both studies indicate further that expanding the intervention with a mindfulness component might drastically reduce this duration up to under a week. The results indicate that adding mindfulness can improve contact to nature interventions depending on the change in mindfulness induced. While the numerical results presented in this thesis have limitations rooted in the data basis and the assumptions made, they still show that

mathematical formalization based on existing data, can foster our understanding of interventions effects and pinpoint directions how to improve them.

Limitations

Although the present research clearly shows the potential of mathematical formalization to derive more information about the potential effects of interventions, it is appropriate to recognize several potential limitations, especially for the numeric results. The main limitation lies in the data used. As it was not specifically gathered for this purpose it is not ideal for all calculations but finding these limitations is also part of the test of the potential of mathematical formalization based on pre-existing data. Due to the data mainly being limited to two or respectively three conditions some of the assumptions made when developing the equations could not be specifically tested. These include the assumption of linearity for the effects of the following days, which could potentially fluctuate, decrease, or in cases that differ from the data used here even increase over time. To further investigate this, more specific data with more data points would be needed. Similarly, it was also not possible to differentiate main and interaction effects of the added mindfulness component as there was no data for a condition with only the effects of mindfulness. With more specified data this could be investigated better. Splitting up these effects more clearly might lead to even more advanced equations than those found in this thesis.

A more conceptual limitation is the combination of data from a long-term intervention with that from a brief contact to nature intervention from two different samples. While it provides an initial approximation, it is important to keep in mind, when interpreting these insights or building upon them, that differences in the nature of the studies and between the sampled may have influenced the results presented here.

Despite these limitations, the results of this thesis show that applying mathematical formalization on pre-existing data can uncover additional information and generate insights to inform

and improve connection to nature interventions. The derived models and results based on them were without additional data generation used to develop directions for future research and practical considerations. Similar outcomes are potentially possible for other research areas and interventions.

Directions for Future Research

The results obtained indicate two avenues for future research, investigating mathematical formalization further with different data sets or research areas and building upon the insights found on connection to nature interventions. Following the first avenue researchers should tests utilizing equations such as the ones developed here as an additional way to evaluate the efficacy of other interventions. For other areas of research further applications depending on the questions of interest in them and the data generated there are possible; in some cases, these applications might be achieved by simply formalizing and rearranging existing relationships. For those interested in improving connection to nature interventions building upon this research a relevant step would be to generate data specifically to test the models developed in this thesis. To be able to model the relationship in more detail data needs to be generated following a more long-term intervention in shorter intervals, to get a better understanding of the development of the effects across the following days. Other questions raised in this thesis like, what is the relationship between change in mindfulness and change in connection to nature, also offer interesting directions for future research. An avenue not followed further in this research, but with potential for practically relevant insights is the idea of utilizing the higher effects of the initial day by combining multiple shorter interventions across a longer time. Overall, this underscores that mathematical formalization not only holds great potential to answer existing questions but can also guide future research by generating interesting hypotheses that inform planning and implementation of future research.

Conclusion

The results of this thesis imply that simply sending people to experience nature is not a feasible intervention, as inducing a higher level of connection to nature would take 26 days or more. However, it also showed that complementing contact to nature interventions with mindfulness components could potentially improve contact to nature interventions significantly to reduce the needed time down to around a week. To reach these conclusions about connection to nature interventions and how to potentially improve them formalizing relationships mathematically was a helpful tool. It can improve our understanding of effects found in intervention studies and what measures might be taken to strengthen them. As the general approaches used here are not limited to intervention research per se, utilizing mathematical formalization more has potential for other areas of research as well. Overall, the findings suggest that mathematical formalization is a useful means to develop a better understanding of interventions and carve out promising directions for future research.

References

Barlett, P. F. (2008). Reason and reenchantment in cultural change. *Current Anthropology*, *49*(6), 1077–1098. https://doi.org/10.1086/592435

Barton, J., Bragg, R., Pretty, J., Roberts, J., & Wood, C. (2016). The wilderness expedition. *Journal of Experiential Education*, *39*(1), 59–72. https://doi.org/10.1177/1053825915626933

Barton, J., & Pretty, J. (2010). What is the best dose of nature and green exercise for improving mental health? A multi-study analysis. *Environmental Science & Technology*, *44*(10), 3947–3955. https://doi.org/10.1021/es903183r

Bolouki, A., McAnirlin, O., H. E. M. Browning, M., & Maynard, A. (2025). Optimizing virtual nature for psychological and physiological well-being: A systematic review of the moderating effects of duration, nature type, sample characteristics, and immersiveness and potential risks of bias. *International Journal of Human–Computer Interaction*, *41*(1), 775–791. https://doi.org/10.1080/10447318.2024.2338327

Braun, T., & Dierkes, P. (2017). Connecting students to nature – how intensity of nature experience and student age influence the success of outdoor education programs. *Environmental Education Research*, *23*(7), 937–949. https://doi.org/10.1080/13504622.2016.1214866

Brown, K. W., & Ryan, R. M. (2003). The benefits of being present: Mindfulness and its role in psychological well-being. *Journal of Personality and Social Psychology*, *84*(4), 822–848. https://doi.org/10.1037/0022-3514.84.4.822

Capaldi, C., Passmore, H.-A., Nisbet, E., Zelenski, J., & Dopko, R. (2015). Flourishing in nature: A review of the benefits of connecting with nature and its application as a wellbeing intervention. *International Journal of Wellbeing*, *5*(4), 1–16. https://doi.org/10.5502/ijw.v5i4.449

Cohen, J., & Cohen, P. (1983). *Applied multiple regression/correlation analysis for the behavioral sciences* (2nd ed.). Erlbaum.

Coughlan, A., Ross, E., Nikles, D., Cesare, E. de, Tran, C., & Pensini, P. (2022). Nature guided imagery: An intervention to increase connectedness to nature. *Journal of Environmental Psychology*, *80*, 101759. https://doi.org/10.1016/j.jenvp.2022.101759

Funder, D. C., & Ozer, D. J. (2019). Evaluating effect size in psychological research: Sense and nonsense. *Advances in Methods and Practices in Psychological Science*, *2*(2), 156–168. https://doi.org/10.1177/2515245919847202

Kals, E., Schumacher, D., & Montada, L. (1999). Emotional affinity toward nature as a motivational basis to protect nature. *Environment and Behavior*, *31*(2), 178–202.

Kesebir, S., & Kesebir, P. (2017). A growing disconnection from nature is evident in cultural products. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *12*(2), 258–269. https://doi.org/10.1177/1745691616662473

Lau, M. A., Bishop, S. R., Segal, Z. V., Buis, T., Anderson, N. D., Carlson, L., Shapiro, S., Carmody, J., Abbey, S., & Devins, G. (2006). The toronto mindfulness scale: Development and validation. *Journal of Clinical Psychology*, *62*(12), 1445–1467. https://doi.org/10.1002/jclp.20326

Lengieza, M. L., & Swim, J. K. (2021). The paths to connectedness: A review of the antecedents of connectedness to nature. *Frontiers in Psychology*, *12*, 763231. https://doi.org/10.3389/fpsyg.2021.763231

Mayer, F. S., & Frantz, C. M. (2004). The connectedness to nature scale: A measure of individuals' feeling in community with nature. *Journal of Environmental Psychology*, *24*(4), 503–515. https://doi.org/10.1016/j.jenvp.2004.10.001

Mayer, F. S., Frantz, C. M., Bruehlman-Senecal, E., & Dolliver, K. (2009). Why is nature beneficial? *Environment and Behavior*, *41*(5), 607–643. https://doi.org/10.1177/0013916508319745

Microsoft Corporation. *Microsoft Excel for Microsoft 365* (Version 2505) [Computer software]. https://office.microsoft.com/excel

Nisbet, E. K., Zelenski, J. M., & Grandpierre, Z. (2019). Mindfulness in nature enhances connectedness and mood. *Ecopsychology*, *11*(2), 81–91. https://doi.org/10.1089/eco.2018.0061

Schultz, P. W. (2001). The structure of environmental concern: Concern for self, other people, and the biosphere. *Journal of Environmental Psychology*, *21*(4), 327–339. https://doi.org/10.1006/jevp.2001.0227

Schutte, N. S., & Malouff, J. M. (2018). Mindfulness and connectedness to nature: A meta-analytic investigation. *Personality and Individual Differences*, *127*, 10–14. https://doi.org/10.1016/j.paid.2018.01.034

Sellmann, D., & Bogner, F. X. (2013). Effects of a 1-day environmental education intervention on environmental attitudes and connectedness with nature. *European Journal of Psychology of Education*, *28*(3), 1077–1086. https://doi.org/10.1007/s10212-012-0155-0

Suppes, P. (1968). The desirability of formalization in science. *The Journal of Philosophy*, *65*(20), 651. https://doi.org/10.2307/2024318

Tam, K.-P. (2013). Concepts and measures related to connection to nature: Similarities and differences. *Journal of Environmental Psychology*, *34*, 64–78. https://doi.org/10.1016/j.jenvp.2013.01.004

Unsworth, S., Palicki, S.-K., & Lustig, J. (2016). The impact of mindful meditation in nature on self-nature interconnectedness. *Mindfulness*, *7*(5), 1052–1060. https://doi.org/10.1007/s12671-016-0542-8

van Dam, N. T., van Vugt, M. K., Vago, D. R., Schmalzl, L., Saron, C. D., Olendzki, A., Meissner, T., Lazar, S. W., Kerr, C. E., Gorchov, J., Fox, K. C. R., Field, B. A., Britton, W. B., Brefczynski-Lewis, J. A., & Meyer, D. E. (2018). Mind the hype: A critical evaluation and prescriptive agenda for research on mindfulness and meditation. *Perspectives on Psychological Science : A Journal of the Association for Psychological Science*, *13*(1), 36–61. https://doi.org/10.1177/1745691617709589

Vining, J., Merrick, M. S., & Price, E. A. (2008). The distinction between humans and nature: Human perceptions of connectedness to nature and elements of the natural and unnatural. *Human Ecology Review*, *15*(1), 1–11. https://www.jstor.org/stable/24707479

Whitburn, J., Linklater, W., & Abrahamse, W. (2020). Meta-analysis of human connection to nature and proenvironmental behavior. *Conservation Biology*, *34*(1), 180–193. https://doi.org/10.1111/cobi.13381

Wyles, K. J., White, M. P., Hattam, C., Pahl, S., King, H., & Austen, M. (2019). Are some natural environments more psychologically beneficial than others? The importance of type and quality on connectedness to nature and psychological restoration. *Environment and Behavior*, *51*(2), 111–143. https://doi.org/10.1177/0013916517738312

Appendix

Previous Considerations and Considerations for Part 3: Dynamic Mindfulness

In a preliminary version of this thesis and the presentation of it included a different approach to model the change in connection to nature relative to the change in mindfulness leading to different conclusions. This approach also built upon Equation 3 and a variant of Equation 11, which included additional instances of i:

$c_a = c_b + (b_{day1} i + b_{dayx}(d-1))(i\,(i + m))$. Equation 3 was assumed for interventions without a mindfulness component. For the representation of the change in mindfulness the factors Δm and b_m were also introduced, however, this preliminary version did not contain a separate instance of the effects of the intervention's effects, $b_{day1} i + b_{dayx}(d-1)$, but only the variant that is relative to the change in mindfulness and the conversion factor. As a result, the following formula was obtained for cases including a mindfulness component

$$c_a = c_b + b_m \left(b_{day1} i + b_{dayx}(d-1)\right) \Delta m, \tag{A1}$$

Here Δm represents the change in mindfulness due to the intervention and b_m represents the factor of conversion between this change and the change in the effects. The other terms used are explained under Equation 3 and Equation 10 and symbols are described in Table 1.

As there is no data regarding negative changes in mindfulness and changes in mindfulness are expected to be positive when a mindfulness intervention is used, no equation part for negative changes in mindfulness was developed. To account for cases without a change in mindfulness as well, an equation for all cases that have no, or a (positive) change in mindfulness was created by combining both formulas into a piecewise function, resulting in

$$c_a = \begin{cases} c_b + b_{day1} i + b_{dayx}(d-1), & for\ \Delta m = 0 \\ c_b + b_m \left(b_{day1} i + b_{dayx}(d-1)\right) \Delta m, & for\ \Delta m > 0, \end{cases} \tag{A2}$$

for every value of ($\Delta \mathrm{M} \geq 0$) and where $i \in \{0,1\},\ d \in \mathbb{N}$.

To be able to do calculations to investigate implications for the duration of the intervention, the lower part of the equation describing cases with a positive change in mindfulness was solved for number of days needed, leading to

$$d = \frac{\frac{c_a - c_b}{b_m * \Delta m} - b_{day1} * i}{b_{dayx}} + 1. \quad \text{(A3)}$$

For the calculations the same approximation of b_m described in Part 3 was used leading to $b_m = 2.22$ and inserted with the data also used in Part 3 data (($\Delta m = 0.36$; $c_b = 3.94$; $b_{day1} = 0.32$; $b_{dayx} = 0.03$; $c_a = 5$) into Equation A3. Resulting in

$$d = \frac{\frac{\mathbf{5 - 3.94}}{\mathbf{2.22 * 0.36}} - \mathbf{0.32 * 1}}{\mathbf{0.03}} + 1 = 33.54 \quad \text{(A4)}$$

Similarly, the same scenarios as in Part 3 were inserted into Equation A4 to get a better overview over the influence of the change in mindfulness: A low change scenario with half of the change found in the study ($\Delta m = 0.18$), a higher change scenario with one and a half times this change ($\Delta m = 0.54$) and a high change condition with double this change ($\Delta m = 0.72$). The detailed results can be found in Table A1. In contrast to the current findings presented in Part 3, only the higher- and high-change scenarios would lead to an improvement over to the 26 days found in Part 1 for interventions not having a mindfulness component in the intervention. This led to the question at which change of mindfulness in the intervention, the duration of the intervention can be reduced in comparison to an intervention not using mindfulness. To be able to calculate this, the part of Equation A2 referring to cases with a change in mindfulness was rearranged to calculate Δm, resulting in

$$\Delta m = \frac{c_a - c_b}{b_m \left(b_{day1} i + b_{dayx} (d - 1) \right)} \quad \text{(A5)}$$

Inserting the same data again and inserting d = 25.66 calculated in Equation 8 into this equation, results in

$$\Delta m = \frac{\mathbf{5} - \mathbf{3.94}}{\mathbf{2.22}\left(\mathbf{0.32} + \mathbf{0.03}(\mathbf{25.66} - 1)\right)} = 0.45, \quad \text{(A6)}$$

which indicates that an intervention needs to induce at least a change greater than 0.45 in mindfulness to result in a reduction of the duration of the intervention.

Similarly, it was calculated how much change in mindfulness would be needed to reduce the duration of the intervention to reach the eight days calculated in Part 2 in Equation 16 by inserting d = 8 in Equation A5, resulting in

$$\Delta m = \frac{5 - 3.94}{2.22\left(0.32 + 0.03(\mathbf{8} - 1)\right)} = 0.90. \quad \text{(A7)}$$

Figure A 1

Different changes in mindfulness and their required intervention duration to reach higher Connection to Nature

Case	Change in mindfulness (Δm)	Duration in days to 5 on the INS scale (C*onnection to Nature*)
1 (low)	0.18	79
2 (average) - Nisbet et al. (2018)	0.36	35
no mindfulness – Part 1	***0.45***	**26 (25.66)**
3 (higher)	0.54	20
4 (high)	0.72	12
Similar change to Part 2	***0.90***	**8**

These results were previously interpreted in the following: Both these changes in mindfulness are greater than the change found in Nisbet et al. (2019), indicating either that the model developed here does not correctly account for cases $\Delta m \leq 0.45$ or that to low change in mindfulness might actually reduce the effectiveness of the intervention.

The main difference between this older model and the new version is that the new variant assumes that the main effect of the intervention is always there, while the older version assumes all effects to be dependent on the change in mindfulness. The new version fits better with the data in the two studies, which indicates that it is the better model but to conclusively determine which model holds up in other cases as well, further data is needed.

Discussion of effects of dynamic mindfulness (old version)

Based on these findings the following Discussion was formulated for the preliminary version of Part 3:

> In this part additional formulas to calculate the potential values after an intervention considering a more dynamic relationship between the added mindfulness component and the change in Connection to Nature, were developed. These can and were used to calculate the potential reduction in intervention duration for different changes in mindfulness. The results indicate that adding a less effective mindfulness intervention ($\Delta \mathrm{m} < 0.45$) might reduce the effectiveness of contact to nature interventions and that for the reduced duration found in Part 2, a great change in mindfulness would be needed ($\Delta \mathrm{m} = 0.9$). … [shortened as the further parts are similar to what is still in the current version of the Discussion]

Overall, these results led to conclusions in the presentation and the preliminary version of the thesis that are mostly consistent with those in the current version. The main difference lies in a boundary found for the size of change in mindfulness. The preliminary version indicates that the change in

mindfulness needs to be greater than 0.45 units on the *Toronto Mindfulness Scale* to lead to a reduction in the number of intervention days needed. The other conclusions remained similar: simply sending people to experience nature may not be a feasible intervention, as increasing the score on the INS scale to 5 could take up to 26 days. More data on the dynamics of these processes is needed to properly test the derived models. Additionally, formalizing intervention effects can lead to a better understanding of these effects and inform how to improve future interventions