Exploring the use behaviour in web-based complaint-directed mini-interventions for people with depressive symptoms through log data analysis

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Abstract

Background: Web-based complaint-directed mini-interventions (CDMIs) on worry, sleep, and stress were developed with the aim of depression prevention. This intervention was found to be effective in reducing depressive complaints in a two-armed randomized controlled trial (RCT) published in 2017. However, it is yet unknown how the use behaviour of participants in this web-based intervention contributed to these outcomes.

Objective: The objective of the study is to gain insight into CDMI use behaviour and how this relates to the RCT follow-up depression scores.

Methods: Log data gathered from 168 CDMI active users enrolled in the RCT study were used to conduct an explorative study. Using linear regression, the RCT results were analysed to explore if there is a dose-response relationship between the follow-up depression scores and aspects of intervention use behaviour (active period, active days, total performed exercises, unique exercises). Additionally, the log data was used to construct various visualisations in 'R' which allows to gain detailed insight on CDMI usage.

Results: The linear regression did not detect significant relations between intervention outcomes on depression and the total number of exercises (P=.954), the active period (P=.37), or the number of active days (P=.63). The improvement in depression score in the subset of the current explorative study, which includes only the participants who performed at least one exercise, is larger compared to the original RCT data. A large group of participants (40%) used the intervention for a single day, and 20% adheres to the advice of the intervention designers to use the intervention for at least four weeks. The log data also illustrated that the order of exercises in the interface of the intervention does make a difference in the chance of being selected by the user; the first exercises of each module were performed most often.

Conclusions: The absence of dose-response relationships showed that difference in depression scores cannot be attributed to aspects of use behaviour. The initial use (performing at least one exercise) may be considered to be the effective engagement for this intervention since the effect on depression score is more positive when non-users are excluded. This raises the question whether it is necessary to create extensive eHealth interventions, or if the same result may be achieved with less intensive interventions consisting of effective components. Improvement in depressive complaints may be attributed to the motivation of people to work on their complaints. The current intervention may be improved by transferring the CDMIs into an app that makes use of reminders, and by placing exercises that are considered most important first in the module.

Introduction

Of the Dutch population, 18.7% of the inhabitants have experienced a depressive episode in their lives (de Graaf, ten Have, & van Dorsselaer, 2010; Nuijen et al., 2017). Depression is characterized by episodes of depressed mood, loss of interest, loss of enjoyment, and reduced energy (Nuijen et al., 2017; WHO, 2018). The government of the Netherlands has invested in depression prevention due to the increasing burden of disease for the individual as well as the national societal financial consequences (Olesen, Gustavsson, Svensson, & Jo, 2012; Spijkerman et al., 2014). A strategy increasingly developed and applied for depression prevention is the use of eHealth interventions, a rapidly growing field that encompasses the application of digital technology in the service of health promotion (Eldredge, Markham, Ruiter, Kok, & Parcel, 2016). eHealth is found to be effective in decreasing symptoms of depression as well as preventing the occurrence of depression (Cuijpers, Van Straten, Warmerdam, & Van Rooy, 2010; Kelders, Bohlmeijer, Pots, & van Gemert-Pijnen, 2015; Zoonen, Buntrock, Ebert, Smit, & Reynolds, 2014).

The Trimbos Institute has developed complaint-directed mini-interventions (CDMIs), an e-mental health intervention for depression prevention. CDMIs aim to reduce depressive symptoms by focussing on three complaints that are associated with (a developing) depression, are highly prevalent, and are associated with high costs: sleep, worry, and stress (Smit, Majo, Boon, Ruiter, & Abspoel, 2011). However participants were advised to spend two to three hours a week for a period of at least four weeks on the CDMIs, the participants can choose freely which exercises they want to perform at which moment (Lokman et al., 2017). The CDMIs were found to be effective in reducing depressive complaints in people with mild-to-moderate depressive symptoms (Lokman et al., 2017; Spijkerman et al., 2014). Despite knowing the effect of the CDMIs on depressive symptoms, it is yet unknown how participants use the intervention. The limited insight on how the use of eHealth technology contributes to the user's improved well-being is a familiar issue among eHealth development and evaluation (Sieverink, Kelders, Poel, & van Gemert-Pijnen, 2017). The reason for this is the lack of transparency on how users behave in an intervention and which elements are related to intended outcomes (e.g. how many days people have been using the intervention, or the number of performed exercises). Since the amount of use that is needed to obtain the desired outcomes may vary across different users groups, it is suggested that users may not have to experience all available elements of an eHealth intervention because the usage goals for each individual may differ (Donkin, Christensen, Naismith, Neal, et al., 2011; Sieverink, Kelders, & Gemert-pijnen, 2017).

Objective and continuous insights to the actual usage of the different components of online interventions can be obtained by analysing log data, which are anonymous records of actions performed by each user (Sieverink, Kelders, Poel, et al., 2017). Advantages of using log data include that it does not require any extra effort from the participants, it is always available, and easy to collect. Log data analysis can be of great value to eHealth because it can provide objective insights into how the usage of technology contributes to effects found in randomised controlled trials (RCTs) (Sieverink, Kelders, Poel, et al., 2017). Therefore, log data analysis is an appropriate strategy to gain more in-depth knowledge on use behaviour and depression score outcomes of the RCT conducted on the web-based CDMIs by Lokman et al. (2017). It would be of additional value to identify the way of engagement with the intervention that is related to achieve intended outcomes (Yardley et al., 2016).

We aimed to perform an explorative study to gain insight into CDMI use behaviour and how they relate to follow-up depression scores. The first aim is to continue on the RCT results and analyse if there is a dose-response relationship between the follow-up depression scores and aspects of intervention use behaviour (active period, active days, total performed exercises, unique exercises). Following the results of the first aim, the next aim is to describe the way the intervention (components) was used by participants with aid of various visualisations. The outcomes of this analysis may aid in improving the current intervention interface and comparable eHealth interventions.

Methods

Setting

Intervention

As is illustrated in figure 1 and more extensively in the supplementary materials, each of the three CDMIs contain three or four modules with each module consisting of four to six exercises matching the theme of the module. The exercises are largely based on cognitive behavioural techniques and incorporates elements from positive psychology, mindfulness, and solution-focused therapy (Lokman et al., 2017). The participants were free to choose when to perform which exercise, and it was possible to repeat exercises.

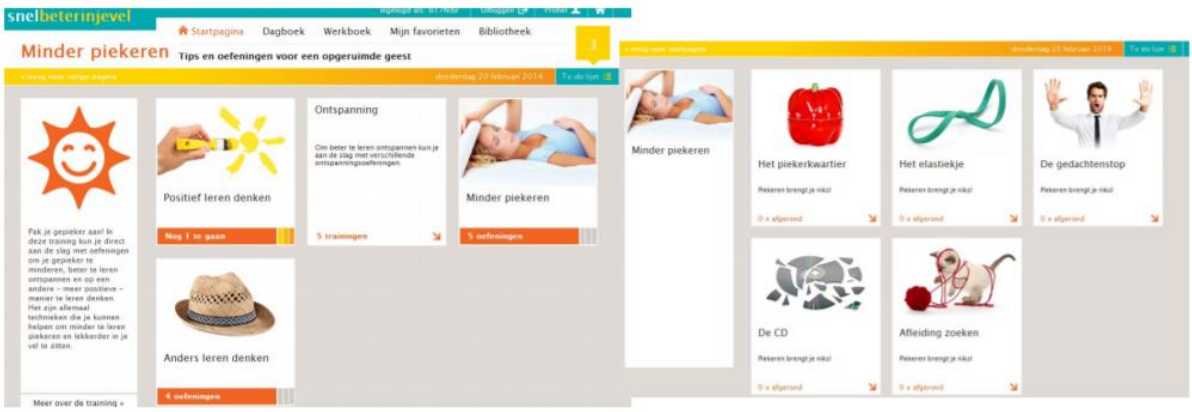

Figure 1. Screenshots of the worry CDMI, and exercises in module 'worry less'

The worry CDMI consists of 18 exercises which are distributed into four modules with the themes 'positive thinking', 'relaxation', 'worry less', and 'learn to think differently'. The module 'positive thinking' consists of four exercises focused on learning a positive way of thinking. 'Relaxation' consists of five audio-instructed exercises (also available in written form) in which participants learn stress management techniques. The module 'worry less' consists of five exercises aimed at acquiring skills to reduce worry or ruminative thoughts by a collection of practically applicable techniques. The last module in the worry CDMI is 'learn to think differently', in which users learn to recognise and change dysfunctional attitudes.

The sleep CDMI consists of 19 exercises which are distributed into four modules with the themes 'sleeping habits', 'relaxation', 'worry less', and 'learn to think differently'. The module 'sleeping habits' includes five exercises that aim to provide more insight into a healthy sleep hygiene and learn skills to break bad sleeping habits. The modules 'relaxation', 'worry less', and 'learn to think differently' have the exact same content as the corresponding modules in the worry CDMI.

The stress CDMI consists of 15 exercises which are distributed into three modules with the themes 'learn to think differently', 'relaxation', and 'boost your energy'. The modules 'learn to think differently' and 'relaxation' have the same content as described before in the corresponding modules in the worry CDMI. The module 'boost your energy' contains six exercises aimed at recharging a person's energy level and handling stress.

Previous evaluations

The CDMIs were developed to fulfil a need for (preventive) interventions for depressive complaints that is suitable for a broad range of target populations, that can easily be implemented with limited costs (Lokman et al., 2017). The CDMIs are not a programme for depression prevention but rather a collection of exercises oriented toward specific complaints instead of the depressive disorder itself, allowing each individual to choose the complaint (worry, sleep, or stress) he or she wants to work on.

The current explorative study aimed at gaining insight into CDMI usage patterns of the participants in the two-armed RCT conducted on the CDMIs. The primary aim of the RCT was to evaluate the effectiveness of the unguided web-based CDMIs in a sample of 329 participants during a period of six months (Lokman et al., 2017). The randomization resulted in 165 participants in the intervention condition who gained access to the intervention right from the start, the other 164 participants were assigned to the control condition in which the participants gained access to the intervention after three months. Participants were free to choose which of the three CDMIs (worry, sleep, or stress) they would like to do. Significant reduction in depressive symptoms was observed as a result for the primary goal of the intervention (P<.001) (Lokman et al., 2017).

Participants

This explorative study following the RCT included the individuals who activated their account and started at least one exercise in the chosen CDMI and therefore consisted of 168 out of the total RCT population of 329 participants. This inclusion criteria resulted in an intervention group of 107 participants and a control group of 61 participants. The 161 participants who did not perform any exercises were excluded from this explorative study of the RCT data. The participants had mild-to-moderate depressive complaints defined as a score of 14 to 38 on the Inventory of Depressive Symptomatology Self-Report (IDS-SR) (Trivedi et al., 2004).

Procedure

The participants chose to be enrolled in one of the CDMIs for worry, sleep or stress during the RCT period of six months. Participants were advised to use the intervention for a period of at least four weeks (Lokman et al., 2017). The IDS-SR measurements took place at baseline (T0), at three months (T1), and at six months (T2) after baseline. The intervention group immediately gained access to the intervention, while the control group gained access after three months. Therefore, the log data includes performed exercises of 107 participants of the intervention group during a period of six months (T0 – T2) and performed exercises of 61 participants of the control group during a period of three months (T1 – T2).

Measurements

The primary aim of the RCT was to evaluate the effectiveness of the unguided web-based CDMIs on depressive complaints as measured by the IDS-SR. A higher IDS-SR score equals more present depressive symptoms. The secondary aim of the RCT was to evaluate the effects of the CDMIs on stress (Perceived Stress Scale), worry (Penn State Worry Questionnaire), sleep (Jenkins Sleep Evaluation Questionnaire), anxiety (Generalized Anxiety Disorder Scale), and well-being (Warwick-Edinburgh Mental Well-being Scale).

For this explorative study, solely the results of the IDS-SR at the three assessments were used. The intervention group in the RCT (Lokman et al., 2017) had an IDS-SR score difference between T0 and T1 of -5.40 (P<.001) while T2 versus T1 is -0.41 (P = .68). The outcome of the IDS-SR score of the control group at T1 was -0.84 (P=.24) and -4.25 between T1 and T2 (P<.001) in the RCT (Lokman et al., 2017).

Data preparation and definitions

During the current explorative study, the demographic information, IDS-SR scores, and log data of performed exercises were used. Demographic information was collected through a self-report online questionnaire at baseline of the RCT and included the gender, age, chosen CDMI, and condition (intervention or control). This data, supplemented with IDS-SR score results of T0, T1 and T2, was collected and stored in a SPSS file that has been used for the analysis of the RCT and made available to continue the current explorative study. The difference in depression score between T0 and T2 will be used in the analysis of the data since this contains the period all 168 participants show activity, this will be referred to as the effect variable. Log data retrieved from the CDMIs was stored in a spreadsheet and included an overview of exercises done by each participant and the corresponding date of performed

exercises. The variables ‘active period’, ‘active days’, ‘total performed exercises’, and ‘unique exercises’ (table 3) were constructed from the spreadsheet with saved exercises and timestamps (table 1). Table 1, 2, and 3 illustrates the variables used for the current explorative study, using participant 25 as an example.

Table 1. *Segment of log data.*

Participant ID	Exercise	Exercise count	Date
25	MP_herh	1	4-8-2014
25	MP_herh	2	4-8-2014
25	MP_compl	1	4-8-2014

Each participant has a unique participant ID. In the column ‘exercise’, the code refers to a specific exercise in the CDMI. The ‘exercise count’ demonstrates how often a specific exercise is performed. The date corresponds to the day the exercise is performed.

Table 2. *Overview of abbreviations and variables*

Abbreviation/variable	Definition
CDMI	Complaint-directed mini-interventions: Worry less, Sleep better, Stress less.
Total performed exercises	The number of all exercises a participant started, including repeated exercises.
Unique exercises	The number of unique exercises a participant started, ignoring repeated exercises.
Active period	The difference in days between the first and the last exercise a participant started. An active period of 0 means participants used the intervention on a single day.
Active days	The number of days on which at least one exercise is started during the active period.
IDS-SR	Inventory of Depressive Symptomatology Self-Report.
Effect variable	The difference in depression score (IDS-SR) between T0 and T2.

Table 3. *Segment of selected and new variables*

Participant ID	Gender	Age	CDMI	Condition	Total performed exercises	Unique exercises	Active period	Active days
25	Female	40	Worry less	Intervention	3	2	0	1
RCT	RCT	RCT	RCT	RCT	New variable	New variable	New variable	New variable

IDS-SR T0	IDS-SR T1	IDS-SR T2	Difference T0 - T1	Difference T1 - T2	Effect variable (difference T0 - T2)	T0 date
30	14	12	-16	-2	-18	13-7-2014
RCT	RCT	RCT	New variable	New variable	New variable	RCT

This table consists of existing RCT data (participant ID, gender, age, CDMI, condition, IDS-SR T0/T1/T2 and the date T0 has been assessed) and new variables (total performed exercises, unique exercises, active period, active days, differences T0-T1/T1-T2/T0-T2).

Data analysis

The software environment 'R' for statistical computing and graphics, used world-wide for the analysis of data, has been used for the analysis of the log data of the RCT (Crawley, 2015). All demographic information as well as use behaviour aspects were calculated or selected in R to compose a table containing an overview of the intervention group (n = 107), the control group (n = 61), and the total included population (n = 168). The table consists of variables retrieved from the RCT, including age (mean, SD, range), gender (n and %), chosen CDMI (n and %), and differences in IDS-SR score (mean and SD) of T0-T2 / T0-T1 / T1-T2. Additionally, the table includes the new variables 'active period' (mean, SD, median), 'active days' (mean, SD, median), 'total performed exercises' (mean, SD, median) and 'unique exercises' (mean, SD, median). Independent samples t-tests were performed on the age and effect variable. A proportion test was applied on the gender and the division of 1 day / 2-30 days / 30> days in the active period. The non-parametric Mann-Whitney U test was performed on variables of active period, active days, total performed exercises, and unique exercises because these variables were not normally distributed.

The RCT primary outcomes showed that the CDMIs had a positive effect on the depression symptoms. The first goal in the current explorative study was to look if there is a dose-response relationship between the depression score results and aspects of use behaviour. This way, we aim to determine if the depression score decreases more if the total number of performed exercises increases, if the period of activity increases, or if the active days increases. The total performed exercises, the active period of intervention use, and the active days of intervention use were aspects shown as independent variable on the x-axis and related in three figures to the effect variable on the y-axis. Different colours and shapes distinguished the CDMI and condition of each participant. Multiple linear regression was performed to assess the relation between the difference in depression scores and various activity measures, while correcting for intervention. We report the beta estimate of the activity measure of interest (B) and its 95% confidence interval (CI). Additionally, a visualisation of the effect variable was composed in two plots with the variables active period (x-axis) and total performed exercises (y-axis), and active period (x-axis) and unique exercises (y-axis). Colour indicates the difference in depression score between T0 and T2 with white as a neutral score, red as an increase in IDS-SR score, and green as a decrease in IDS-SR score. The data visualisation package ggplot2 has been applied in R to construct the scatterplots.

The next aim was to explore the intervention use behaviour participants show and to gain more detailed information about the usage of intervention components. The active period, active days, total performed exercises and unique exercises were illustrated with ggplot in R as scatterplots. First, the active period was visualised in weeks (x-axis) with the total performed exercises (y-axis). The CDMI and condition for each participant was characterized by different colours and shapes to allow us to compare the CDMIs and control or intervention conditions. Next, the active period (x-axis) was related to the unique exercises (y-axis) and thus ignoring repeated exercises. Since the maximum number of exercises differed for each CDMI, these plots were presented separately for each CDMI in the results section.

In order to zoom in on what participants actually did during their active days, dot charts were constructed. These charts show for all three CDMIs the distribution of when each participant performed exercises during their active period. The control group and intervention group were labelled by different shapes, and repeated exercises are to be recognized by their increasing size. In another set of dot charts, an overview of all modules and exercises is shown including which exercises each participant performed and repeated. This gives information about the popular exercises, popular exercises to repeat, and whether the participants navigate through the exercises randomly or according the order offered in the web-based intervention. Since a lot of participants used the intervention for a single day (39.3%), similar dot charts were constructed to show what single-day users did on the only day they performed exercises.

Finally, attention was paid to the specific modules and exercises to show what themes and exercises participants used most. For each CDMI, a bar chart was constructed of all exercises ordered by frequency on the y-axis for each module, and a pie chart provides an overview of the percentages of how much exercises are chosen for each module. The exercises were coded and listed according to the CDMI and order it was presented in the intervention. The first number corresponds to the module and the second number the exercise. For example, ‘worry 1-2’ is the code of the second exercise in the first module as presented in the interface of the intervention.

Results

In total, 168 participants were included for the explorative study following the RCT. Table 4 shows an overview of the intervention group (n = 107), the control group (n = 61) and the total number of participants (n = 168) on age, gender, chosen CDMI, differences in IDS-SR score of T0-T2 / T0-T1 / T1-T2, and intervention use behaviour aspects. The participants had a mean age of 42.8 (SD 12.6, range 18-74) years and the majority were female (72.6%, 122/168). Of the 168 participants in both conditions, 65 (38.7%) participated in the worry CDMI, 48 (28.6%) participated in the sleep CDMI, and 55 (32.7%) participated in the stress CDMI.

Comparing three intervention months of both groups (T0-T1 for intervention group and T1-T2 for control group), the average IDS-SR scale score for both the experimental and the control group decreased, meaning a reduction in depressive symptoms. The improvement in depression score in the subset of the current explorative study, which includes only the participants who performed at least one exercise, is larger compared to the original RCT data. The intervention group in the RCT (Lokman et al., 2017) had an IDS-SR score difference of -5.40 (P<.001) while the subset of the current explorative study that actually used the intervention had an IDS-SR score difference of -6.7 points. The outcome of the IDS-SR score of the control group was -4.25 (P<.001) in the RCT (Lokman et al., 2017) while the subset of participants who actually used the intervention scored -7.1. Since there is no significant difference (P=.17) on the effect variable between the intervention and the control group, the groups will be combined for further analysis. The effect variable, the mean difference between T0 and T2 of both groups combined, is -7.0.

Since there is a nonparametric right-skewed distribution of the active period, active days, total performed exercises, and unique exercises, the Mann-Witney U test has been performed on these variables. The intervention group was significantly more active on all measured use behaviour aspects compared to the control group; active period (P<.05), active days (P<.05), total performed exercises (P=.05), and unique exercises (P<.05). A median active period of 6 days for the intervention group and 0 for the control group (meaning a single day active) shows that there is a difference of six days between the two conditions in the active period the participants have used the CDMIs. During the active period, the intervention group (mean = 16, median = 11 exercises) performed on average four exercises more than the control group (mean = 12, median = 7 exercises).

On average, participants used the intervention over a period of 18.3 days (median = 4 days) whereas the total average number of days on which participants actually performed exercises during the period of activity is 3.4 days (median = 2 days). Sixty-six participants (39.3%) carried out the intervention exercises on a single day, while 70 participants (41.7%) used the intervention for a period of 2 to 30 days, and 32 participants (19.0%) used the intervention over 30 days. The mean total number of exercises participants did is 14.6 exercises with a maximum of 110 and a median of 9, while 8.3 exercises is the average of unique exercises participants started with a median of 7. The difference between the total and unique exercises shows that some people have repeated exercises.

Table 4. *Characteristics and CMDI use behaviour aspects of the intervention group, the control group, and the total participants.*

Characteristics	**Intervention group (n = 107)**	**Control group (n = 61)**	**P-value**	**Total (n = 168)**
Age (years)				
Mean (SD)	42.4 (12.1)	43.6 (13.4)	0.55	42.8 (12.6)
Range	18-74	20-71		18-74
Gender, n (%)				
Female	78 (72.9 %)	44 (72.1 %)	1.0	122 (72.6 %)
Male	29 (27.1 %)	17 (27.9 %)		46 (27.4 %)
CDMI, n (%)				
Worry	42 (39.3 %)	23 (37.7 %)		65 (38.7 %)
Sleep	33 (30.8 %)	15 (24.6 %)		48 (28.6 %)
Stress	32 (29.9 %)	23 (37.7 %)		55 (32.7 %)
Difference IDS-SR score				
T0 – T2, mean (SD)	- 5.7 (11.3)	- 8.3 (6.7)	0.17	- 7.0 (9.4)
T0 – T1, mean (SD)	- 6.7 (8.3)	- 1.8 (7.9)	<0.01	- 4.4 (8.4)
T1 – T2, mean (SD)	+ 1.3 (9.2)	- 7.1 (8.4)	<0.01	- 2.9 (9.7)
Active period				
Mean, difference in days (SD)	20.9 (31.9)	13.8 (22.6)	<0.05	18.3 (29.0)
Median	6	0		4
1 day, n (%)	33 (30.8 %)	33 (54.1 %)	<0.01	66 (39.3 %)
2 – 30 days, n (%)	51 (47.7 %)	19 (31.1 %)	0.05	70 (41.7 %)
30 > days, n (%)	23 (21.5 %)	9 (14.8 %)	0.39	32 (19.0 %)
Active days				
Mean, days (SD)	3.7 (4.4)	3.0 (3.6)	<0.05	3.4 (4.0)
Median	2	1		2
Total performed exercises				
Mean (SD)	16.0 (16.7)	12.0 (13.0)	0.05	14.6 (15.5)
Median	11	7		9
Unique exercises				
Mean (SD)	9.0 (5.6)	7.3 (5.3)	<0.05	8.3 (5.6)
Median	8	5		7

To explore whether there is a dose-response relationship between the difference in depression score and the number of exercises, the period of use, or the active days, the plots in figure 2 were constructed. Of the 168 participants, 95 completed both the T0 and T2 assessment and thus are part of this analysis. Figure 2A, 2B, and 2C show a regression line at IDS-SR difference -7. This matches the results of the RCT regarding the results that the average depression score has improved during a period of six months (Lokman et al., 2017). No significant relations were found between the depression score difference at T2 and the total number of exercises (figure 2A), the active period (figure 2B) or the number of active days (figure 2C). The horizontal regression line in figure 2A implies that this improvement in depression scores is not dependent on the total number of performed exercises (B=-.004, SE=.07, P=.954). In figure 2B, the linear regression line decreases slightly to -10 as the length of the active period increases. However, this is not significant (B=-.03, SE=.03, P=.37). The active days are illustrated in figure 2C and shows a slight but insignificant decrease in depression score when the numbers of days spend on the CDMI increased (B=-.13, SE=.28, P=.63). The linear regression did not detect a dose-response relationship for these three variables.

Based on figure 2D and 2E, there appears to be no pattern in which participants improve or decline in their depression scores. No relationship can be identified in figure 2D between the active period, total performed exercises, and when participants improve or decline in their depression scores. Neither can a relationship be identified in figure 2E between the active period, unique exercises, and when participants improve or decline in their depression scores. Extreme scores, both green and red, occur inconsistent in all plots.

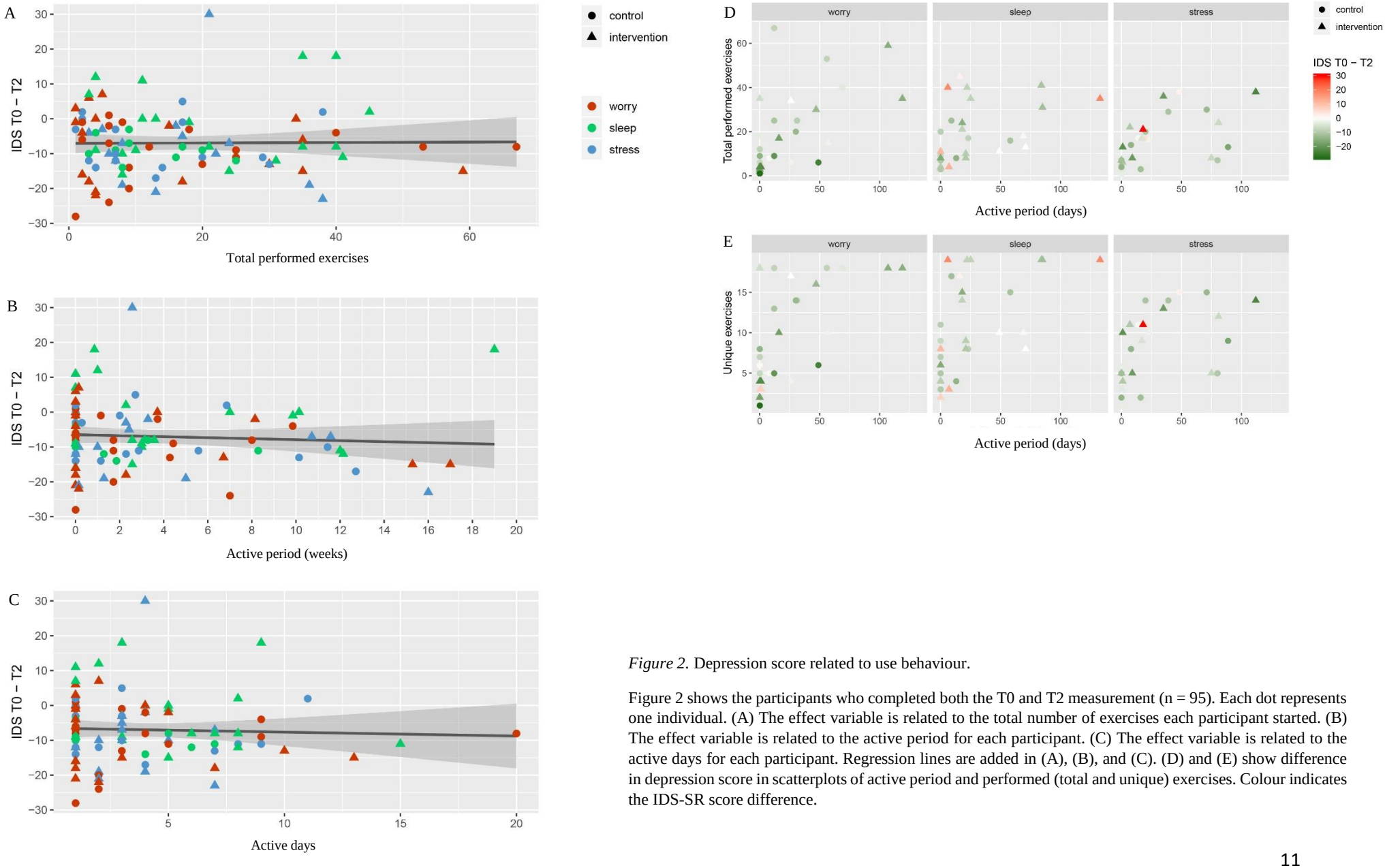

Figure 2. Depression score related to use behaviour.

Figure 2 shows the participants who completed both the T0 and T2 measurement (n = 95). Each dot represents one individual. (A) The effect variable is related to the total number of exercises each participant started. (B) The effect variable is related to the active period for each participant. (C) The effect variable is related to the active days for each participant. Regression lines are added in (A), (B), and (C). (D) and (E) show difference in depression score in scatterplots of active period and performed (total and unique) exercises. Colour indicates the IDS-SR score difference.

The participants were advised to use the chosen CDMI for period of at least four weeks. As shown in figure 3, most participants (136 of 168) were active less than four weeks. In fact, table 4 illustrated that 19.0% of the total participants used the intervention for 30 days or longer and thus used the intervention according to the recommended amount of time. Figure 3A illustrates that the participants in the worry, sleep, and stress CDMI all show similar use behaviour regarding the active period and total performed exercises. As the active period increases, the participants are distributed more in the scatterplot whereas the first two weeks are more crowded. Six participants of the intervention group used the intervention longer than three months, which equals the longest possible period for the control group. In figure 3B, it is shown that the number of unique exercises increases as the active period gets longer. The maximum number of unique exercises in the three plots in figure 3B differ since the number of exercises vary for each CDMI. In the worry CDMI, 15.4% of the participants performed the maximum number of unique exercises (maximum of 18), as did 16.7% of the sleep CDMI (maximum of 19) and 9.1% of the participants of the stress CDMI (maximum of 15).

Figure 3 does not provide any information about the distribution of days on which a participant performed exercises. Looking at an example of the outliers, one participant of the sleep CDMI in the intervention condition has an active period of 19 weeks and performed 35 exercises. Possibly, this person performed 34 exercises on day one and a single exercise at day 133 but it might also be more evenly distributed. In this specific case, the person has been active for nine days. To gain more insight in the distribution of days in which exercises have been performed, figure 4 was constructed.

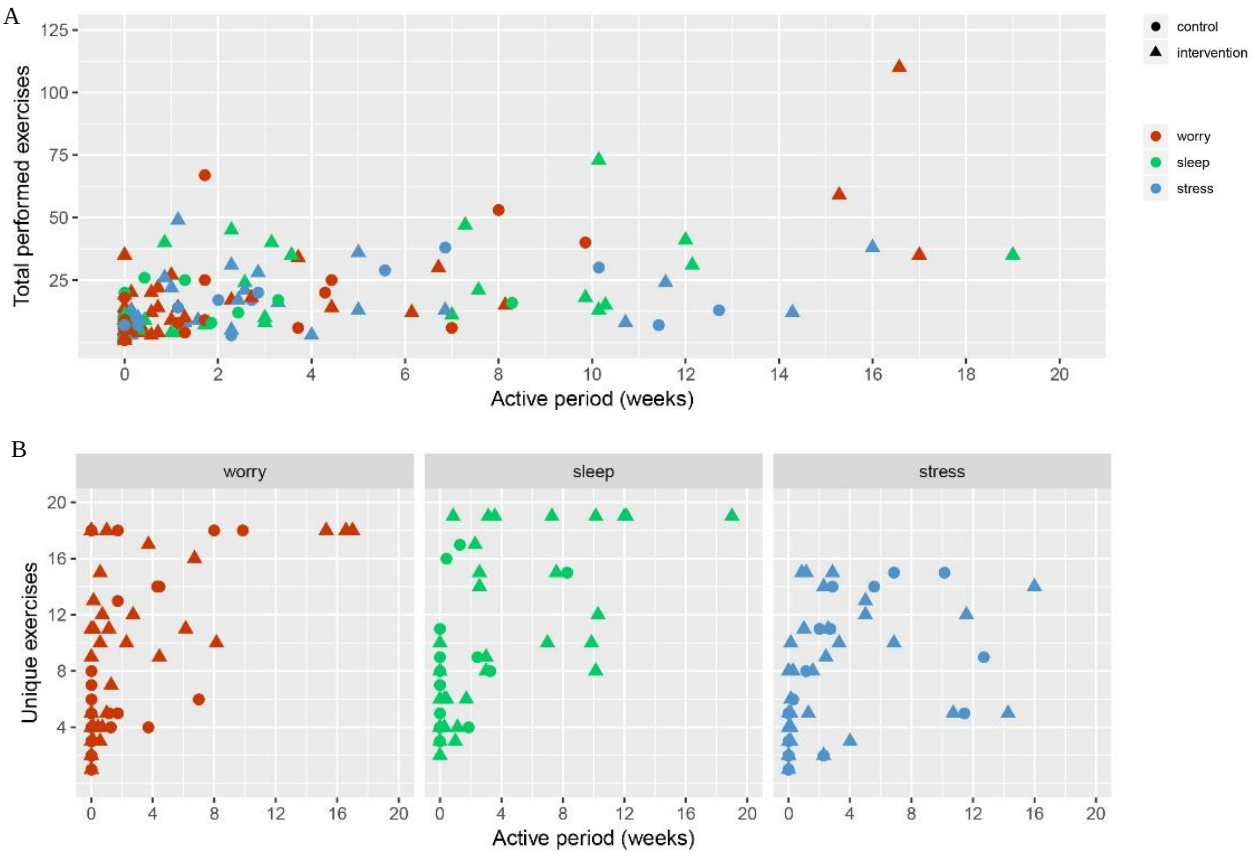

Figure 3. Active period related to the number of performed (total and unique) exercises.

Each dot represents one participant, the colour represents the different CMDIs and the shape distinguishes the control and intervention group. (A) Relates the active period to the total number of exercises each user started. (B) Relates the active period to the number of unique exercises for each CDMI.

The distribution of exercise logs of participants is illustrated in figure 4. There is a great variety in the way participants used the intervention. The number of participants differs for each CDMI, but the use behaviour appears similar among all groups. Since the intervention group had longer availability of the intervention, their period of activity (the highest dot for each participant) can be higher than the control group. Six participants of the intervention group used the intervention longer than the three months the control group had access. Besides regular and irregular users, there is the single-day use group that consists of 39.3% of the participants. With respect to the worry CDMI (n = 65), 29 participants used the intervention for one day. For the sleep CDMI (n = 48), 18 participants used the intervention on one day, as did 19 participants of the stress CDMI (n = 55).

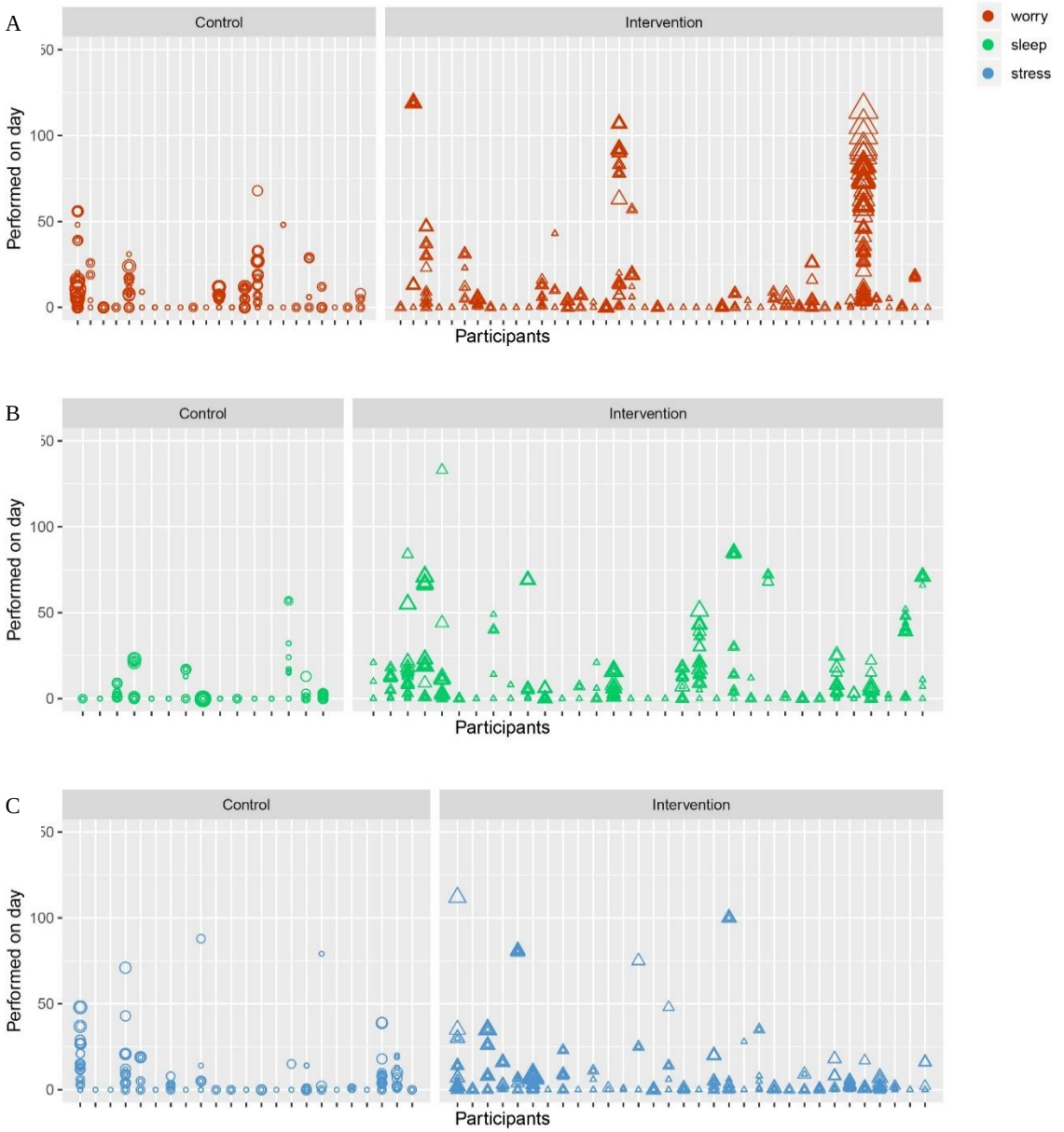

Figure 4. Distribution of exercises performed per participant for each CDMI.

The distribution of when exercises (y-axis) are started per participant (x-axis) for the control group and the intervention group for the (A) worry, (B) sleep, and (C) stress CDMI. Each exercise is illustrated as one dot on the day of activity. The top marking for each participant represents the active period, the number of different days with a marking in this period represents the active days, and repeated exercises can be identified by size (each time a particular exercise is repeated, the circle/triangle will increase).

In figure 5, exercises each participant performed are indicated as well as how often the exercises are repeated. A similar figure for single-day users can be found in the supplementary materials. It is shown that some people perform each exercise at least once, others choose one or a couple of exercises, and there is a group of people who perform exercises repeatedly. There are exercises that are performed by almost all participants (e.g. sleep 1-1: test to check whether you are an evening or a morning person) while others are chosen very few (e.g. sleep 3-5: looking for distraction when worrying thoughts occur).

In the module 'positive thinking' of the worry CDMI (n = 65), all exercises are encouraged to be performed repeatedly. Figure 5A shows that people do indeed repeat exercises in this module more often compared to, for example, the 'worry less' module in which tips are given to deal with worrying thoughts and can be applied by reading the instructions once. In the sleep CDMI (n = 48), the exercises in the module 'sleeping habits' are chosen most. With an exception of two individuals, all participants of the sleep CDMI performed at least one exercise from this module which makes it more popular compared to the other modules. In the worry and sleep CDMI, there are several exercises most people perform. However, for the stress CDMI (n = 55) there is only one exercise that shows the same pattern (stress 1-1: recognise helping and impeding thoughts).

Figure 5. Overview of performed exercises.

An overview of how often each exercise is performed by participants for the (A) worry, (B) sleep, and (C) stress CDMI, categorized by module. The chronological order of the exercises matches the order in which the exercises are located in the interface of the online intervention. Exercise names in Dutch corresponding the codes on the y-axis can be found in supplementary materials. Circles represent the control group, triangles represent the intervention group, and increasing size represents repeated exercises.

In the ordered bar charts and pie charts in figure 6, the frequency exercises and modules have been chosen are shown. What is demonstrated in figure 6A is that all first exercises of each of the four modules are performed most often in de worry CDMI. This is also the case for three of the sleep CDMI modules and for one of the three modules for the stress CDMI. The CDMI-specific modules are most popular for all CDMIs.

The most performed exercise for the worry CDMI is worry 1-1 (repeating positive thoughts, frequency = 109) while the least performed exercise is worry 2-4 (relaxation through self-massage, frequency = 27). In the worry CDMI, the module 'positive thinking' (31%) has been most popular, followed by 'worry less' (24.8%), 'relaxation' (23.8%), and 'learn to think differently' (20.4%). The most often performed exercise for the sleep CDMI is sleep 1-5 (learning to increase hours of sleep, frequency = 93) while the least performed exercise is sleep 2-4 (relaxation through self-massage, frequency = 20). The most popular module in the sleep CDMI is 'sleeping habits' (35.1%). This is followed by 'relaxation' (26.6%), 'learn to think differently' (20.4%) and 'worry less' (17.9%). For the stress CDMI, the most often performed exercise is stress 1-1 (recognise helping and impeding thoughts, frequency = 92) and the least performed exercise stress 3-3 (reflecting on important personal values, frequency = 31). The stress CDMI's most popular module is 'boost your energy' (34.9%), followed by 'learn to think differently' (34.1%) and 'relaxation' (31.0%).

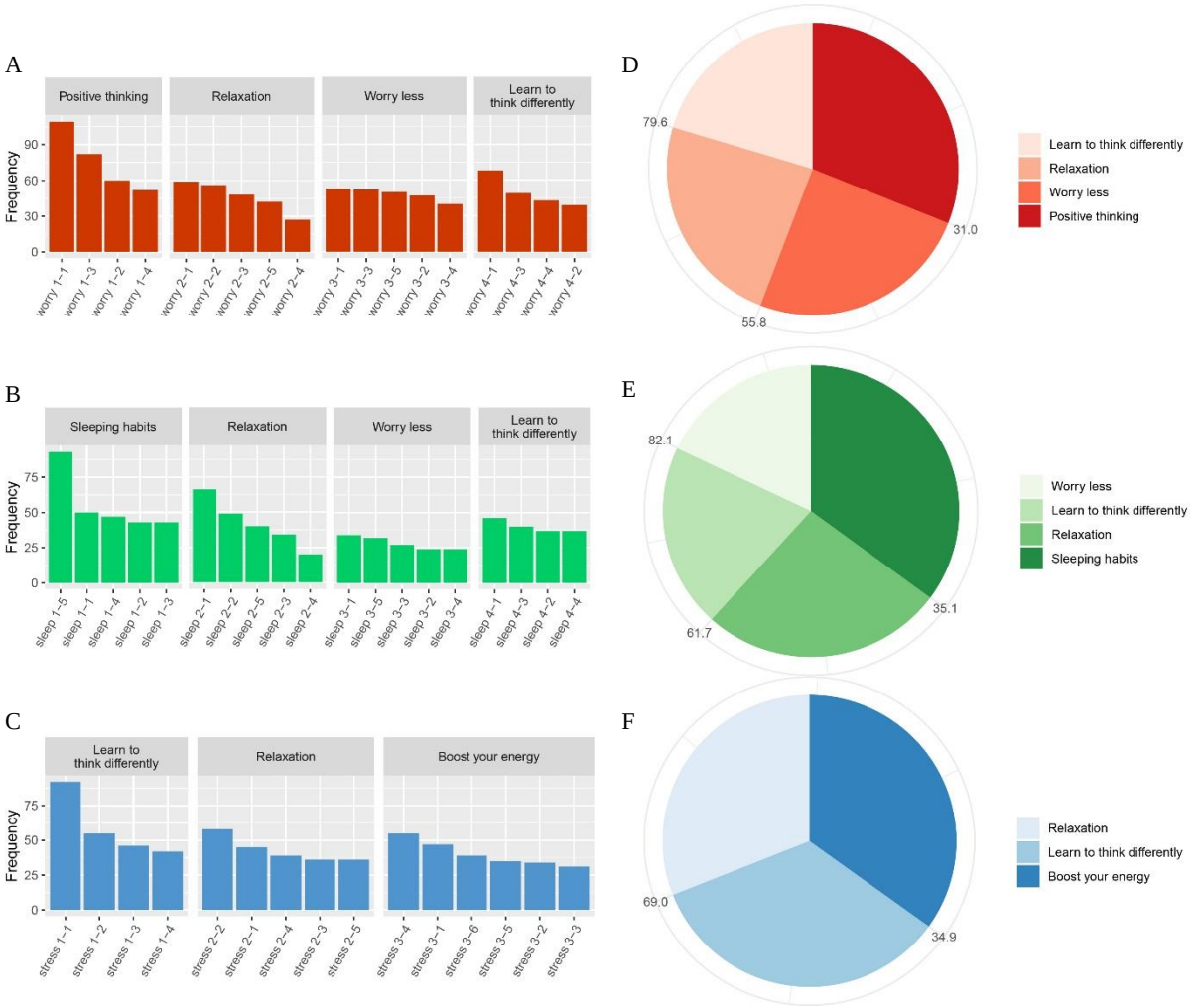

Figure 6. Frequency of chosen exercises and corresponding modules for each CDMI.

An overview of how often each exercise is performed, and ordered by module for the (A, D) worry, (B, E) sleep, and (C, F) stress CDMI. Adding all exercises in one module results in pie charts with corresponding percentages. Exercise names in Dutch corresponding the codes can be found in supplementary materials.

Discussion

Principal findings

The log data analysis made it possible to provide insight in the relationship between use behaviour and found effects in the RCT; the first aim of the current explorative study. The missing dose-response relationships showed that difference in depression scores cannot be attributed to the active period, the active days, or the total number of exercises performed. These results are similar to a RCT by Donkin (2013) on determining if there is a dose-response relationship between usage and outcome in an online intervention for depression. In this article the intensity of use appeared to give little additional effect on outcomes as well. However, the authors of this article suggest that assumptions of a linear relationship between use and outcomes may be too simplistic and analysis of other variables need to be explored to adequately understand the relationship (Donkin et al., 2013). We applied this view in the current explorative study by supplementing the linear regression with more detailed information through visualizing the variables active period, active days, total performed exercises, and unique exercises.

According to Yardley et al. (2016), 'effective engagement' is defined as sufficient engagement with the intervention to achieve intended outcomes. There appears to be diverse ways participants use the intervention, and these ways appear to show no dose-response relationship or pattern when it results in positive or negative outcomes. As mentioned in other studies on eHealth as well, the working elements may differ for each individual in order to reach their goal (Donkin, Christensen, Naismith, Neal, et al., 2011; Sieverink, Kelders, & van Gemert-Pijnen, 2017). The difference in effect variable between the RCT group (n = 329) (intervention: -5.40, control: -4.25) and the subset (n = 168) of this explorative study (intervention: -6.7, control: -7.1) suggests that the subgroup has influence on the depression score difference, because the effect is more positive when non-users are excluded. Therefore, the initial use (spend at least one exercise on one day on the intervention) may be considered to be the effective engagement for this intervention. A question is raised regarding the content of eHealth about whether it is necessary to create extensive interventions, or if short ones fulfil the need. The same result may be achieved with less time, less money, and less effort.

The active period, active days, total performed exercises, and unique exercises are use behaviour elements retrieved from the log data that provide insight on how participants used the online CDMIs and intervention components; the second aim of this study. A key observation describes a remarkable group of users; the 66 participants who used the intervention on a single day. Despite the CDMIs were longer available during the RCT for the intervention group, only six participants used the intervention longer than three months; the longest possible period for the control group. This suggests that the intervention is not used much for a long-term period. Possibly, the goals for the users are reached by then. In general, there appear to be three main groups of users: the single-day users, the regular users who perform exercises relatively evenly distributed in their active period, and the irregular users who show one or several gaps in their active period.

A high attrition rate is described more often in web-based interventions, but may not per se result in less positive outcome (Donkin et al., 2013). The results in the current study match this view and show that the intensity of CDMI usage shows no relation to the outcomes. Being motivated and willing to work on complaints may result in behaviour change and positive intervention outcomes (Mohr, Cuijpers, & Lehman, 2011; Yardley et al., 2016). Transferring this view on the CDMIs may suggest that the improvement in depressive complaints may be attributed to the fact that people are motivated to work on their complaints regardless of the use behaviour participants show. It may as well explain the extra decrease of depression score on the subset of this study compared to the original RCT, since the subset consists of participants who performed at least one exercise and thus are likely to have better outcome results because of the presence of motivation.

Practical value

The results of the log data analysis can be of added value for eHealth developers for the current CDMIs as well as other eHealth interventions. There is a large group of participants who show minimal intervention use by performing exercises on one day (39.3%) or by performing few exercises. Based on the depression results being better in the subset of active users compared to the total RCT population, there is a possibility that even more intervention usage may result in a more positive intervention outcome that was not significantly shown in this explorative study due to a small sample size. Participants can be supported with use of an app which allows them to use the intervention in more contexts and according to their own preferences, as well as by applying prompts in the form of reminders (Michie, Johnston, Francis, Hardeman, & Eccles, 2008; Yardley et al., 2016).

An often described problem of self-help interventions is the amount of treatment participants receive because of attrition (Andersson et al., 2005; Christensen, Griffiths, & Jorm, 2004; Eysenbach, 2005; Kohl, Crutzen, & de Vries, 2013; Meglic et al., 2010). This phenomenon matches the results of this explorative study, which show that almost 40 percent of the participants stop using the intervention after their first day and is also shown in the attrition in completing assessments. This raises the question what the effective components of eHealth really encompasses. The participants of the CDMIs were advised to spend at least four weeks on the intervention. In fact, people who adhered to this advice did not structurally score better than people being active on one day. Adherence and effective engagement are concepts focussing on how to get users involved (Yardley et al., 2016). Instead of eHealth prescribing guidelines for users, it is advisable to match the eHealth intervention on the user's preferences in order to reach effective adherence and engagement (Eldredge et al., 2016). To include the potential users in the intervention process as main stakeholders is one way to reach this goal, for example by interviewing participants about their likes and dislikes and how their behaviour may have contributed to the outcomes. The log data analysis of this study suggests a wish for short interventions with practically applicable techniques to deal with their complaints. It would be of additional value to check with use of questionnaires or interviews whether this suggestion correlates with the user experience.

The log data visualisations provide insight regarding the interface of the intervention. The results of this explorative study show that even though participants can navigate through the intervention freely, it appears that the order in which exercises are offered in the intervention has effect on which ones are performed most frequently. The first exercise in each module is in general performed most often. Therefore, designers of eHealth interventions should consider carefully in what order they will offer the exercises. Exercises that are believed to be most important for users to perform should best be located first in the module. Focussing on the modules, the CDMI specific modules ('positive thinking' for the worry CDMI, 'sleeping habits' for sleep CDMI, and 'boost your energy' for stress CDMI) are used most often. This is not unexpected because the title and content of these modules are likely to fit the needs of participants choosing for that particular CDMI. eHealth designers should therefore be aware of the influence of titles and the order in the interface of the intervention. The advice given to the participants to use the intervention for four weeks does not match the reality of how people use the intervention. Instead, advise should best be restrained or emphasise that users could use it according to their own goals and needs. With follow-up research, it would be interesting to identify logical goals and determine the advice matching these specific goals.

Continuation of current explorative study

For the continuation of the current study it would be interesting to look at the 161 participants who did not perform any exercises and thus were excluded from this explorative study of the RCT data. It would be of additional value to give meaning to the fact that 161 people did not perform any exercises and to compare the characteristics and IDS-SR results of the people who did not and who did perform exercises. When, for example, patterns are found in gender, age, or severity of depression complaints at T0, then the approach to potential users can be targeted more specifically.

For this explorative study, solely the results of the IDS-SR at the three assessments were used because the results of this questionnaire gave the largest sample size since the depression scale was relevant for all users. If the complaint-specific questionnaires would be included, the results between T0 and T2 of 35 worry CDMI users, 30 sleep CDMI users, and 30 stress CDMI users could be analysed. However, even though the sample sizes would be small, it would be of additional value to analyse the outcome results of the Penn State Worry Questionnaire for the worry CDMI, the Jenkins Sleep Evaluation Questionnaire for the sleep CDMI, and the Perceived Stress Scale for the stress CDMI. This way, the log data results can provide an indication on the effect on the specific complaint as addition to the overarching depression assessments.

The log data of performed exercises was used for this study. However, more data has been stored for each participant. For each CDMI, people can make use of a diary. In here, people can keep track of their sleeping schedule, burden they experience because of worrying thoughts, burden they experience because of stress, and an indication of their mood in general. Also, people can save exercises as a favourite and there is a to-do list with an overview of exercise answers and reminders to repeat exercises. To gain more insight in the use behaviour of participants, it would be interesting to look into these data as well and relate this to the effect variable. When people show activity by filling in the diary when not doing exercises, the user may actually be more engaged than shown in the used log data and thus provides a more complete overview of use behaviour.

The current explorative study was executed according to a quantitative approach. However, additional quantitative or qualitative questions can provide extra information about the results. From a clinical point of view, it would be interesting to analyse which specific exercises contribute to a change in depressive complaints and what these exercises characterizes. Another aim would be to select both the positive and negative extremes regarding IDS-SR score difference and compare their use behaviour. Possibly, patterns can be identified in effective and non-effective engagement that are more obvious than the current results. Additionally, interviews with the users may provide insight in if and how the content of the intervention is applied in their daily life.

Methodological considerations and limitations

There are several limitations in this study which may distort the result outcomes. For the depression related analysis, the first aim of the study, the difference between T0 and T2 is taken because this includes performed exercises from both the intervention and the control condition. While there are individuals in both groups who do and do not significantly experience effect out of the intervention, there is no significant difference (P=.17) between both condition groups, which is an argument in favour of using this effect variable including both conditions. However, there is missing data because not all participants completed the T2 measurement and this resulted in a smaller sample size of 95 participants. This seems small considering the original group from the RCT consisted of 329 participants and was already reduced to 168 for this explorative study. Another option was to take the difference in the period T0 to T1 for the intervention group and T1 to T2 for the control group. This choice should be made early in the data preparation phase because not all performed exercises should be included thus a selection of the corresponding period should have been made. However, this does not necessarily lead to more participants because of missing data of T1 as well. This attrition on assessment points is a problem that

occurs in more studies and a clear solution suitable for all eHealth interventions has yet to be identified (Donkin, Christensen, Naismith, Hons, et al., 2011; Warmerdam, van Straten, Twisk, Riper, & Cuijpers, 2008).

Another note regarding the selected period is that the complete period between T0 and T2 is taken for the analysis of performed exercises. The comparison between the intervention group and the control group may not be realistic since the intervention group was able to use the intervention longer. An alternative approach is to select the activities between T0 and T1 for the intervention group and the period between T1 and T2 for the control group. There is chosen not to apply this because we wanted to grasp the full potential of the obtained log data which includes how participants use the intervention during the available time. In practise, only six participants of the intervention group used the intervention longer than three months, which equals the longest possible period for the control group. Still, it may distort the outcomes slightly thus the cut off of three months is to be considered seriously.

Interventions like the current one are known to be difficult to define engagement because participants are able to sustain engagement outside of the intervention technology (Yardley et al., 2016). Despite of the log data, we still do not have full insight into the behaviour of the users. The log data seems to picture formal intervention use rather than engagement. Some exercises allow the user to work on their complaints offline since they can be copied, or audio files can be downloaded. Other exercises describe a technique or tool which can be applied in daily life without having to repeat the exercise. This is not registered in the log data and thus not included in the analysis. A recommendation to tackle this issue is to make it possible to monitor the behaviour of participants, for example by not making it able for participants to download audio files but having to use an app instead. For researchers, this will make the analysis easier but is likely to decrease the offline adherence and optimal use of the intervention because it discourages users to practise the new behaviour in daily situations.

In conclusion, the log data visualizations did fulfil the wish to gain insight into CDMI use behaviour aspects. It is shown that these behaviour aspects do not relate to RCT follow-up depression scores. Recommendations for the current CDMIs include that the intervention may be improved by locating exercises that are considered most important first in the module and by transferring the CDMIs into an app that makes use of reminders. Future research is encouraged for other eHealth interventions to execute comparable log data analysis, even though dose-response relationships on the chosen outcome measures are absent. Comparing visualisations of use behaviour of different eHealth interventions may increase understanding of effective components and effective engagement.

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Supplementary material

Additional information and complaint-directed mini-intervention (CDMI) screenshots

(Lokman et al., 2017)

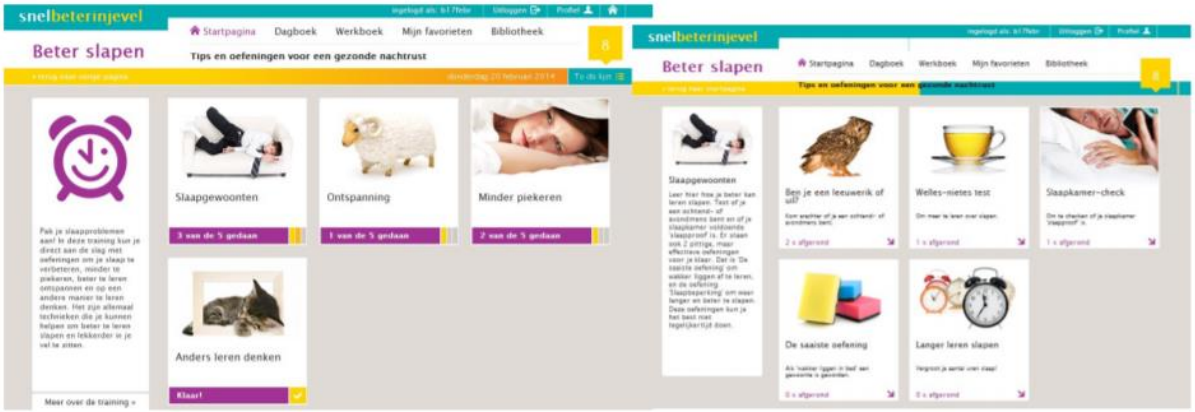
Screenshot of the CDMI homepage

CDMI 'Sleep Better'

This CDMI is for people who experience sleep problems, like having difficulty falling asleep, frequently waking up during the night or waking up too early. Participants learn to manage factors that influence their sleep negatively and learn skills to positively influence their sleeping behaviour.

The training consists of 4 modules/ topics which include a total of 19 exercises:

- Sleeping habits: 5 exercises that aim to provide more insight into your sleeping habits and learn skills to break bad sleeping habits (e.g. check your bedroom).
- Relaxation: 5 exercises to learn relaxation techniques (e.g. progressive relaxation).
- Worry less: 5 exercises aimed at acquiring skills to reduce worry or ruminative thoughts (e.g. 15 minute 'worry time').
- Learn to think differently (about sleep): 4 exercises to learn to recognise and change dysfunctional attitudes about sleep.



Screenshots of the CDMI Sleep Better

CDMI 'Worry Less'

This CDMI is for people who tend to worry a lot and want to change this behaviour. The training consists of 4 modules/ topics that include a total of 18 exercises:

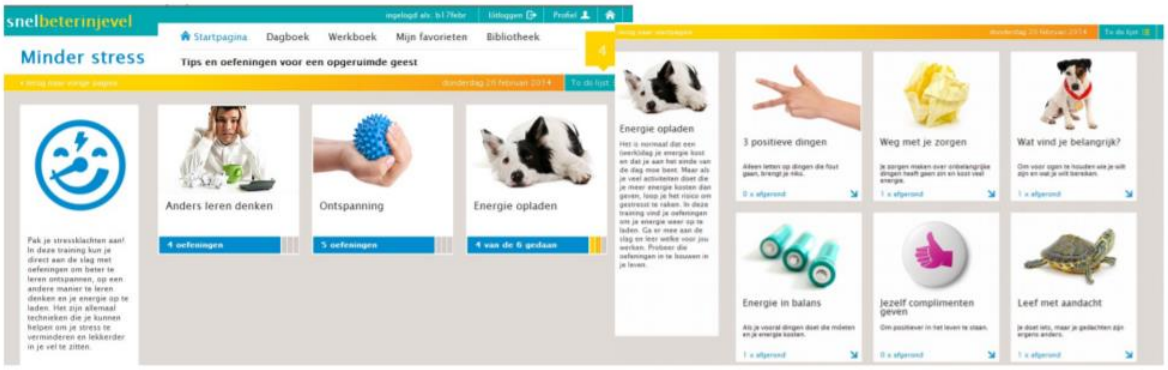
- Positive thinking: 4 exercises focused on learning a positive way of thinking (e.g. 'give yourself a compliment').
- Worry less: 5 exercises aimed at acquiring skills to reduce worry or ruminative thoughts (e.g. 15 minute 'worry time').
- Relaxation: 5 exercises to learn relaxation techniques (e.g. progressive relaxation).
- Learn to think differently: 4 exercises to learn to recognise and change dysfunctional attitudes.

Screenshots of the CDMI Worry Less

CDMI 'Stress Less'

This CDMI is for people who experience (high levels of) stress. The training consists of 3 modules that include a total of 15 exercises:

- Learn to think differently: 4 exercises to learn to recognise and change dysfunctional attitudes.
- Relaxation: 5 exercises to learn relaxation techniques (e.g. progressive relaxation).
- Boost your energy: 6 exercises aimed at recharging yourself and handling stress (e.g. note 3 positive things).



Screenshots of the CDMI Stress Less

Overview of performed exercises of single-day users

Exercises coding scheme

CDMI	Exercise	Name	Code	Module	Module translation
Worry Less	Positieve gedachten herhalen	MP_herh	worry_1-1	Positief leren denken	Positive thinking
Worry Less	Positieve gedachten koppelen	MP_koppel	worry_1-2	Positief leren denken	Positive thinking
Worry Less	Jezelf een compliment geven	MP_compl	worry_1-3	Positief leren denken	Positive thinking
Worry Less	De tijdsprong	MP_tijd	worry_1-4	Positief leren denken	Positive thinking
Worry Less	Ademhalingsoefening	MP_ademh	worry_2-1	Ontspanning	Relaxation
Worry Less	Spierontspanningsoefening	MP_spier	worry_2-2	Ontspanning	Relaxation
Worry Less	Ontspannen via je fantasie	MP_fantasie	worry_2-3	Ontspanning	Relaxation
Worry Less	Ontspannen via massage	MP_massage	worry_2-4	Ontspanning	Relaxation
Worry Less	Ontspannen via je handen	MP_handen	worry_2-5	Ontspanning	Relaxation
Worry Less	Het piekerkwartier	MP_kwartier	worry_3-1	Minder piekeren	Worry less
Worry Less	Het elastiekje	MP_elastiek	worry_3-2	Minder piekeren	Worry less
Worry Less	De gedachtenstop	MP_stop	worry_3-3	Minder piekeren	Worry less
Worry Less	De CD	MP_CD	worry_3-4	Minder piekeren	Worry less
Worry Less	Afleiding zoeken	MP_afleiding	worry_3-5	Minder piekeren	Worry less
Worry Less	Gedachten herkennen	MP_ontdek	worry_4-1	Anders leren denken	Learn to think differently
Worry Less	Gedachten overdrijven	MP_overdrijf	worry_4-2	Anders leren denken	Learn to think differently
Worry Less	Gedachten uitdagen	MP_uitdagen	worry_4-3	Anders leren denken	Learn to think differently
Worry Less	De rollen omdraaien	MP_rollen	worry_4-4	Anders leren denken	Learn to think differently
Sleep Better	Ben je een leeuwerik of een uil?	SL_uil	sleep_1-1	Slaapgewoonten	Sleeping habits
Sleep Better	Welles-nietes test	SL_WN	sleep_1-2	Slaapgewoonten	Sleeping habits
Sleep Better	Slaapkamer-check	SL_kamer	sleep_1-3	Slaapgewoonten	Sleeping habits
Sleep Better	De saaiste oefening	SL_saai	sleep_1-4	Slaapgewoonten	Sleeping habits
Sleep Better	Langer leren slapen	SL_langer	sleep_1-5	Slaapgewoonten	Sleeping habits
Sleep Better	Ademhalingsoefening	SL_ademh	sleep_2-1	Ontspanning	Relaxation
Sleep Better	Spierontspanningsoefening	SL_spier	sleep_2-2	Ontspanning	Relaxation
Sleep Better	Ontspannen via je fantasie	SL_fantasie	sleep_2-3	Ontspanning	Relaxation

Sleep Better	Ontspannen via massage	SL_massage	sleep_2-4	Ontspanning	Relaxation
Sleep Better	Ontspannen via je handen	SL_handen	sleep_2-5	Ontspanning	Relaxation
Sleep Better	Het piekerkwartier	SL_kwartier	sleep_3-1	Minder piekeren	Worry less
Sleep Better	Het elastiekje	SL_elastiek	sleep_3-2	Minder piekeren	Worry less
Sleep Better	De gedachtenstop	SL_stop	sleep_3-3	Minder piekeren	Worry less
Sleep Better	De CD	SL_CD	sleep_3-4	Minder piekeren	Worry less
Sleep Better	Afleiding zoeken	SL_afleiding	sleep_3-5	Minder piekeren	Worry less
Sleep Better	Gedachten herkennen	SL_ontdek	sleep_4-1	Anders leren denken	Learn to think differently
Sleep Better	Gedachten overdrijven	SL_overdrijf	sleep_4-2	Anders leren denken	Learn to think differently
Sleep Better	Gedachten uitdagen	SL_uitdagen	sleep_4-3	Anders leren denken	Learn to think differently
Sleep Better	De rollen omdraaien	SL_rollen	sleep_4-4	Anders leren denken	Learn to think differently
Stress Less	Gedachten herkennen	MS_ontdek	stress_1-1	Anders leren denken	Learn to think differently
Stress Less	Gedachten overdrijven	MS_overdrijf	stress_1-2	Anders leren denken	Learn to think differently
Stress Less	Gedachten uitdagen	MS_uitdagen	stress_1-3	Anders leren denken	Learn to think differently
Stress Less	De rollen omdraaien	MS_rollen	stress_1-4	Anders leren denken	Learn to think differently
Stress Less	Ademhalingsoefening	MS_ademh	stress_2-1	Ontspanning	Relaxation
Stress Less	Spierontspanningsoefening	MS_spier	stress_2-2	Ontspanning	Relaxation
Stress Less	Ontspannen via je fantasie	MS_fantasie	stress_2-3	Ontspanning	Relaxation
Stress Less	Ontspannen via massage	MS_massage	stress_2-4	Ontspanning	Relaxation
Stress Less	Ontspannen via je handen	MS_handen	stress_2-5	Ontspanning	Relaxation
Stress Less	3 positieve dingen	MS_3pos	stress_3-1	Energie opladen	Boost your energy
Stress Less	Weg met je zorgen	MS_zorg	stress_3-2	Energie opladen	Boost your energy
Stress Less	Wat vind je belangrijk?	MS_belang	stress_3-3	Energie opladen	Boost your energy
Stress Less	Energie in balans	MS_balans	stress_3-4	Energie opladen	Boost your energy
Stress Less	Jezelf complimenten geven	MS_compl	stress_3-5	Energie opladen	Boost your energy
Stress Less	Leef met aandacht	MS_aandacht	stress_3-6	Energie opladen	Boost your energy