

**Biocueing for body awareness and emotion regulation for patients with borderline personality disorder: An exploratory multiple baseline design**

Ellen Wolsink<sup>1</sup>, Matthijs L. Noordzij<sup>2</sup> and Farid Chakhssi<sup>1,2</sup>

<sup>1</sup> GGNet, Doetinchem, The Netherlands

<sup>2</sup> Department of Psychology, Health and Technology, University of Twente,  
The Netherlands

**Author note**

Correspondence concerning this article should be addressed to Ellen Wolsink, GGNet, Postbus 2003, 7230 GC Warnsveld, The Netherlands. Email: e.wolsink@ggnet.nl

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### **Abstract**

Emotion dysregulation is considered to be the hallmark of borderline personality disorder (BPD) and may stem from poor body awareness. Biocueing – i.e. providing real-time feedback, in everyday life, on physiological arousal from bodily measurements – shows a promising perspective in augmenting existing treatment approaches for BPD. Aims of this study were to develop a biocueing protocol using a smartwatch application designed specifically for patients with BPD and evaluate its potential efficacy in improving body awareness and emotion regulation using a multiple baseline design. Nine participants with BPD, admitted to residential dialectic behavior therapy (DBT), received 3 weeks of biocueing preceded by baseline measurements that varied randomly (1-3 weeks), and 2 weeks follow-up. Participants reported daily on body awareness, and emotion regulation was evaluated at four different assessment points. Results showed that biocueing has good acceptance and feasibility when added to DBT. No significant effect was found on daily reported body awareness. No reliable change was found on self-reported body awareness and emotion regulation. Concluding interviews revealed an added value of biocueing for interoceptive awareness not captured by the current outcome measure. Thus, more studies with innovative methods for measuring body awareness are needed to examine the role of biocueing for patients with BPD.

*Keywords:* Sense-IT, biofeedback, biocueing, feasibility, acceptance, body awareness, emotion regulation, interoceptive sensibility, borderline personality disorder, dialectical behavior therapy

## **Biocueing for body awareness and emotion regulation during psychotherapy of patients with borderline personality disorders: A feasibility study**

Borderline personality disorder (BPD) is a mental disorder, prevalent in 0.7% to 3.5% of the general population and is characterized by severe difficulties in affect regulation, impulse control, interpersonal relationships, and self-image (American Psychiatric Association, 2013; Doering, 2019). Emotional dysregulation is considered to be the hallmark of BPD (American Psychiatric Association, 2013) and stems in part from poor body awareness (Derks et al., 2017b). Thus, improving body awareness is an important focus in BPD treatment. Existing treatment approaches, with dialectical behavior therapy (DBT) being the most effective, show significant but small effect sizes for BPD pathology, including emotional dysregulation (Cristea et al., 2017). Thus, more research is needed to identify mechanisms that may augment the current efficacy of treatment for emotion dysregulation in BPD.

The use of wearables (i.e. smartphones) and sensor technologies (i.e. smartwatches) show a promising perspective in augmenting existing treatment approaches for BPD (Derks et al., 2017a; ter Harmse et al., 2021a). These sensors can help BPD patients to become more aware of their bodies via biocueing (van Dijk et al., 2015; Quazi et al., 2012). Biocueing is real-time feedback in daily life provided to an individual via biological cues or signals (ter Harmse et al., 2021). Thus, sensors monitor physiological processes (e.g. heart rate) and present these measurements to the individual in real-time using visual, auditory or tactile signals, especially when unlikely values are measured (e.g. very high or low heart rate for that person). These biocues can then be used to for example aid the awareness of changes in physiological arousal in response to emotional cues. They could then be seen as ‘learning material’ and may serve as an aid in recognizing emotions and applying more adequate and appropriately timed self-regulation or emotion regulation skills (Peira, Pourtois, &

Fredrikson, 2013; ter Harmsel et al., 2021a; Yu, 2018). While body awareness is an important aspect of current treatment approaches for BPD, biocueing of physiological arousal is not yet incorporated into these approaches.

Although biocueing sounds promising, research regarding this technology in BPD samples is still lacking. For example, a recent review regarding smartphone applications (including smartwatches) for BPD symptoms showed that these applications did not use biocueing or biofeedback. The applications were used as a platform to offer interventions such as psychoeducation, suicide prevention, or safety plans and teach emotion regulation skills (Ilagan et al., 2020). In a more recent review examining studies using biocueing or ambulatory biofeedback to enhance emotion regulation, positive effects were found on both self-reported and physiological stress. However, only two of these biocueing studies included psychiatric patients and none included BPD samples (ter Harmsel et al., 2021a). Thus, more research is needed to identify the role biocueing may have in augmenting existing treatments for patients with BPD.

Sense-IT is a biocueing application for a smartwatch with an accompanying application on a smartphone. Sense-IT was specifically developed for BPD patients to recognize and monitor their own physiological arousal by signaling deviating heart rate levels, via real-time feedback, in everyday life (Derks et al., 2017a). Sense-IT was developed in collaboration with patients with BPD and their therapists in user-centered design studies. These studies also examined how and when to incorporate Sense-IT in residential DBT (Derks et al., 2019; Hubelitz, 2019; Moorman-van der Kooij, 2019). The next logical step would be to examine the feasibility and clinical value of Sense-IT when added to DBT.

Therefore, we aim to investigate the feasibility and acceptance of Sense-IT when added to DBT for patients with BPD. Furthermore, we examined the preliminary effectiveness of Sense-IT to increase body awareness beliefs. We also evaluated changes in

self-reported emotion regulation and body awareness, which we hypothesized to improve after the Sense-IT intervention.

## Methods

### Design

A multiple baseline design was used, which is designed to examine the effectiveness of an intervention within an individual patient. This methodological approach permits statistical inferences to be drawn related to possible effects of the intervention at the individual level (Kazdin, 2019). The multiple baseline design in this study consisted of three phases. First, a baseline phase where residential DBT was given and the baseline varied randomly in lengths over the participants. The second phase consisted of the Sense-IT intervention. The third phase consisted of two weeks follow-up. The effectiveness of the Sense-IT can be assessed by comparing the baseline data and the intervention data. If changes in the participant's functioning occurred during the Sense-IT intervention, these changes are seen as evidence of the effectiveness of that specific intervention.

### Participants

Participants were recruited from a treatment center for personality disorders where they were admitted to residential DBT. The sample consisted of 9 female patients and 2 therapists. The mean age in the sample was 27.9 years ( $SD = 11.9$ ; range 19 – 60). All patients were diagnosed with BPD according to DSM-5 criteria using the Borderline Personality Disorder Severity Index IV. Figure 1 presents the participant flow. Table 1 presents an overview of the demographic characteristics of the participants. The two participating therapists were a social worker and a clinical psychologist (1 male, age 46; 1 female, age 59).

## **Intervention**

Sense-IT is a biocueing application, using a smartwatch and smartphone. The Sense-IT measures physiological data by the photoplethysmography (PPG) sensor of the smartwatch and directly stores the data on the smartphone. A built-in algorithm calculates a heart rate level between -3 and 5 using the SD of the heart rate at baseline. By default, the algorithm works with the sensitivity category “Normal”, which means that a border crossing to the next level is 1 times the SD. Six participants adjusted the sensitivity to category “High”, which means that a border crossing to the next level is half the SD. The smartwatch showed the current heart rate level and the display (the number of colored circles) changed when the heart rate decreased or increased to another level. For this study, notifying vibrations were sent to the participant at levels -3, 3, 4 and 5. The Sense-IT application used the accelerometer and Google activity recognition algorithms to detect physical activity. In this study, no notifying vibrations were sent when the algorithms detected that the participants were driving a car or engaged in sporting activities (i.e. running or biking). On the smartphone, the user could adjust the smartwatch application to one’s individual settings and keep a diary. In this study, the smartwatch TicWatch Pro 3 and the smartphone Nokia 2.4 with Android 11 were used with the Sense-IT (version 2.57).

## **Instruments**

**System Usability Scale.** The System Usability Scale (SUS) was used to assess the degree of usability of the Sense-IT. The SUS contains 10 items on a five-point scale and has strong reliability and validity (Bangor et al., 2008). Examples of items are: “Is the Sense-IT easy to use?” and “I needed the help of a technical person to be able to use the Sense-IT”. Total scores above 70 indicate acceptance of the system, with better products scoring in the high 70s to high 80s and superior products above 90 (Bangor et al., 2008).

**Client Satisfaction Questionnaire.** To assess the satisfaction of the Sense-IT technology the 'Client Satisfaction Questionnaire (CSQ-8) was used. The CSQ-8 contains 8 items on a four-point Likert scale. This questionnaire has adequate reliability and validity (Attkisson & Zwick, 1982). The higher the score, the higher the satisfaction. Examples of items are: "How satisfied are you about the amount of information the Sense-IT gave you?" and "Would you like to use the Sense-IT in the future?" (Attkisson & Zwick, 1982). According to Smith and colleagues (2014) the scores can be interpreted as poor in the range 8-13, fair in the range 14-19, good in the range 20-25, and excellent when between 26-32.

**Multidimensional Assessment Interoceptive Awareness.** The Multidimensional Assessment Interoceptive Awareness (MAIA-2) was used to measure body awareness. This questionnaire was specifically developed to measure body awareness by self-report, divided over 8 scales, Noticing, Not-Distracting, Not-Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trust. The MAIA-2 has moderate to strong reliability and validity (Mehling et al., 2018).

**Daily measurement of body awareness beliefs.** Four items from the MAIA-2 were selected for daily measurements during baseline, Sense-IT and follow-up phase. The items with the highest factor loadings to the most important scales for this study ('Noticing', 'Self-regulation', 'Body listening' and 'Trusting'), were selected. These 4 items were scored on a visual analogue scale (0-100%). The higher the score, the higher the body awareness. Examples of items are: "I notice when I am uncomfortable in my body" and "I listen for information from my body about my emotional state".

**Difficulties in Emotion Regulation Scale.** In order to assess emotion regulation the brief version of the Difficulties in Emotion Regulation Scale (DERS-18, Victor & Klinsky, 2016) was used. It contains 18 items on five-point scale. The questionnaire has adequate reliability (Hallion, et al., 2018) and validity (Victor & Klonsky, 2016). The lower the score,

the better the emotion regulation skills. Examples of items are: “I have no idea how I am feeling” and “When I am upset, I have difficulty concentrating”.

**Interview.** At the end of the follow-up phase a semi-structured interview with open-ended and closed questions was performed with all participants. Questions asked in this interview with the participants were for example: “When did you use the Sense-IT?” and “What did you think of the feedback given by the application?”. Examples of questions that were asked to the therapists were: “Did the use of the Sense-IT affect the treatment?” and “What did the participants comment about using Sense-IT?”.

### **Procedure**

Ethics approval was obtained from a medical ethical review board (NL 65285.044.18) and the study was registered in the Netherlands Trial Register (NL9597).

All patients admitted to the residential DBT were informed about the study. Nine patients agreed to participate and signed informed consent.

The study consisted of three phases. First, a baseline phase. Participants were randomly allocated to 1 of 4 baseline lengths, varying from 1 to 3 weeks, through simple random allocation by drawing lots. The second phase was the Sense-IT intervention phase in which participants used the Sense-IT for 3 weeks. The last phase was a 2 weeks follow-up phase in which the Sense-IT was not used. Based on recommendations from previous research (Moorman-van der Kooij, 2019), the intervention phase started with 3 sessions about the Sense-IT and body awareness. These sessions were successively focused on physical arousal, emotional arousal, and relaxation. The sessions contained psycho-education, technical explanation about the Sense-IT, using the Sense-IT, and exercises. All phases took place in addition to residential DBT. Also, participants were requested to report daily, during the complete study period, their perceived level of body awareness on a visual analog scale (0-100%). Furthermore, the questionnaires MAIA-2 and DERS-18 were administered at the



start of baseline, before and directly after the Sense-IT phase, and at the end of the follow-up phase. At the end of the follow-up phase, an interview was conducted with the participants.

### **Statistical analysis**

First, descriptives (means and standard deviations) were used to present the scores on the CSQ-8 and SUS. The data from the interviews are presented as a summary of the responses per question.

Next, a graph was created per participant showing mean scores on self-reported body awareness over time plotted per phase (i.e. baseline, Sense-IT, and follow-up).

To assess the differences between baseline, treatment and follow-up phase a multilevel analysis was used. The data in the current study has a hierarchical two-level structure with observations (level 1) nested within patients (level 2). For analysis of the data, we have used a hierarchical linear model that captures variation in the outcome both within and across participants, making it possible to estimate a standardized mean difference effect size that is comparable to what would be obtained from a between-group design. For conducting the multilevel analysis, SCDHLM (Valentine et al., 2016) was used (<https://jepusto.shinyapps.io/scdhlm/>)

For the secondary outcome measures, reliable change analyses were used to assess changes on an individual level in scores on the DERS-18 and MAIA-2. For the reliable change analysis of the MAIA-2, reliability (*Cronbach's alpha* = .74) was used from Mehling and colleagues (2018) and standard deviation from a BPD sample (*mean SD* = .61) from Feick (2020). For DERS-18, reliability (*Cronbach's alpha* = .97) was obtained from Hallion and colleagues (2018). The standard deviation for the DERS-18 (*mean SD* = 1.01) was obtained from Mekawi and colleagues (2021).

## Results

### Feasibility & Acceptance

With a mean total score of 76.4 ( $SD = 12.3$ ; range 63 – 100) on the SUS, acceptance of the Sense-IT in the current study is shown (scores above 70 indicate acceptance). Scores on the CSQ-8, with a mean total score of 22.3 ( $SD = 6.9$ ; range 11 – 32), indicate good satisfaction with the system.

Regarding feasibility questions from the interview, most (7) participants reported positive effects of Sense-IT and would recommend it to others. For these 7 participants the biocueing of Sense-IT was congruent with their physical sensations. For 3 participants, the Sense-IT hindered them in heated conversations because they didn't want the other person to know that they were aroused. The extent to which the smartwatch has been worn varied among the participants. Six participants wore the smartwatch daily during the week, of which two also wore it daily during all weekends. One participant made a conscious choice not to wear the smartwatch constantly. Two participants sometimes forgot to put on or charge the smartwatch. Six participants reported technical problems with Sense-IT; sometimes the connection between the smartwatch and smartphone was lost.

The therapists indicated that Sense-IT did not interfere with the treatment program. When clients got cued by Sense-IT and became more aware of their own arousal, this did not have negative effect on the treatment program. Both therapists would like to see it integrated into residential DBT, especially at the start of treatment, when body awareness plays an important role.

### Preliminary effectiveness

Figure 2 shows the scores on daily measurement of body awareness, per participant. For each participant, it is also denoted in Figure 2 how many weeks the participant has undergone residential DBT at the start of this study. The scores were divided into baseline

and intervention/follow-up phases, and no visible changes in trend were observed across these phases. Multilevel analyses showed that from baseline to intervention/follow-up phase no significant effect was found ( $p = .742$ ,  $t = .329$ ), with an effect size not different from zero ( $d = .03$ , 95%  $CI = -.19 - .26$ ). Total score of daily measurement of body awareness consisted of the mean score of four questions. Analyses of these four questions as an outcome separately also showed no significant effect of Sense-IT from baseline to intervention/follow-up phase (all  $p$ 's  $>.05$ ).

### **Reliable changes**

Table 2 shows the results of the reliable change analyses, from baseline to the end of the intervention phase and from baseline to the end of the follow-up phase, for both MAIA-2 and DERS-18. Scores on the MAIA-2 (body awareness) showed no reliable change for all participants directly after the Sense-IT intervention. At the end of the follow-up, a small proportion of participants (11%) had reliably improved on body awareness. Emotion regulation reliably deteriorated for a third of the sample (33%) after the Sense-IT intervention. However, after the follow-up phase the majority (89%) showed no reliable change.

### **Interview data**

The results from the interviews indicated many positive effects: increased awareness and recognition of (signals of) physical arousal (7 participants) and being forced to think about what led to the physical arousal (4 participants), improved recognition of stimuli that triggered psychological trauma-related symptoms (2 participants), awareness of skills that were helpful to lower heart rate (1 participant) and being able to use these skills earlier to lower or raise the heart rate to prevent dissociation (i.e. disconnection from physical and emotional experiences) or reliving the memories of traumatic experience (5 participants), self-reassurance when the heart rate was normal (2 participants), made arousal more objective

and visual for oneself and others (4 participants), which made it easier to set personal boundaries (2 participants) and for others to offer help on time (2 participants). Some exemplary quotes from the interviews are: “I really missed Sense-IT when it stopped.” (participant 36280), “During Sense-IT I was able to prevent reliving and dissociation by using my skills on time. Now I am always too late again and I have just as many reliving’s and dissociations as before using the Sense-IT.” (participant 36381) and “Sometimes I didn’t understand why it was vibrating, but then I could trace it back afterward. One day I had a panic attack and the watch had been vibrating all day, so it warned me all day that something wasn’t right. It always felt like panic attacks came out of nowhere, but apparently the arousal builds anyway.” (participant 36749).

One participant (36274) however, reported mostly negative effects. She was already focused on physical arousal and the Sense-IT increased her hypochondriacal symptoms. Another participant concluded that the use of Sense-IT was too brief in length (i.e. 3 weeks) to properly assess whether it was really helpful or not.

## **Discussion**

This study aimed to investigate the feasibility and acceptance of a biocueing application, Sense-IT, when added to DBT for patients with BPD. Furthermore, we examined the preliminary effectiveness of the Sense-IT to increase body awareness beliefs. We also evaluated changes in self-reported emotion regulation and body awareness. The results showed good acceptance and feasibility of the Sense-IT when added to DBT. No significant effect was found on daily measured body awareness beliefs, nor did we find any reliable change in self-reported body awareness and emotion regulation. However, in the interviews,

the majority of the participants reported added value on both body awareness and emotion regulation. Below we will discuss our findings.

DBT is the treatment of choice in emotion regulation for BPD (Cristea et al., 2017) and the combination of DBT with biocueing has a high potential of augmenting existing treatment (Derks et al., 2017a; ter Harmsel et al., 2021a). This study is a first step in examining biocueing for BPD in (residential) DBT. Our feasibility results expand on the results of Ter Harmsel and colleagues (2021b), who studied an earlier version of the Sense-IT for feasibility (*mean* 73.1, *SD* 16.2) in forensic psychiatric outpatients with aggressive behavior. In our study, an updated version of the Sense-IT was used, which has led to higher usability (*mean* 76.4, *SD* 12.3). Although the interview results suggest integrating the Sense-IT at the beginning of residential DBT (when body awareness plays an important role), the outcome on the body awareness beliefs or questionnaires did not confirm these suggestions. No differences were observed between the participants with different lengths of residential DBT. Future study is recommended to examine at what moment in DBT the Sense-IT could be inserted.

Results from the interviews, with the majority reporting increased awareness and recognition of (signals of) physical arousal, were in line with two prior studies, in which biocueing had positive effects on self-reported and physiological stress (ter Harmsel et al., 2021a). Mackintosh and colleagues (2017) reported on 58 veterans (aged 24-71 years) with PTSD symptoms, who augmented anger management therapy with a mobile application and heart rate monitor, and compared it to anger management alone. The intervention showed significant results on anger severity and PTSD symptoms but did not differ from the comparison condition. The participants rated the mobile application as helpful and easy to use (Mackintosh et al., 2017). This is in line with the results of the current study. In the same vein, in another study using a personal heart rate monitor, in a sample of adolescents with

anger-related diagnosis or behavior, the majority of these adolescents reported significant decline in anger and aggressive behavior (Savard, 2017).

Considered to be one of the most remarkable results obtained from this study, is that the majority of the participants reported that with help of the Sense-IT, they were more aware of ascending arousal and thereby able to use emotion regulation skills in time to prevent dissociation or reliving of memories of traumatic experiences. Indeed, previous research suggests that psychological trauma disrupts the normal physiological response (van der Kolk, 1994, 2006). It leads to changes in autonomic nervous system parameters such as heart rate (van der Kolk, 1994, 2006). Thus, the integration of cognitive, affective, and somatic responses to trauma may enhance the therapy of psychological trauma (Ogden et al., 2006). Prior studies show that focusing on bodily sensations helps to deal with psychological trauma-related symptoms, such as dissociation and reliving memories of psychological traumatic experiences (Bonilla, 2020). Sense-IT may aid in making bodily responses to psychological trauma more aware and may help in the treatment of psychological trauma.

The questionnaires used in this study contained questions about sensations, cognitions, emotion regulation skills and coping strategies, while the Sense-IT only measured heart rate. Other questionnaires, more closely related to bodily sensations or interoceptive sensibility would seem more congruent with biocueing. Interoceptive sensibility is the capacity to focus on internal sensations and to take them into (cognitive) consideration (Poquérusse et al., 2018). However, a validated questionnaire for interoceptive sensibility was not available at the time of this study.

The current study is a new contribution to long-term experience sampling for both individuals with BPD and body awareness beliefs, both of which have had together scarce attention in recent research. In psychotherapy, the body plays an increasingly important role (Bonilla, 2020). Thus, it could be of value to the therapeutic process, for both the patient and

the therapist, to identify and visualize the level, variation and longitudinal patterns of body awareness and other related constructs (Myin-Germeys et al., 2016).

As any study, this study has its limitations. First, the BPD sample in this study consisted of women only in a residential DBT program, thus the results cannot be generalized to other individuals with BPD.

In summary, our results showed good acceptance and feasibility for Sense-IT when added to DBT for BPD. Participants reported added value on body awareness and emotion regulation, while the results of the outcome measures show no significant effect or reliable changes. Thus, still more research is needed to identify the role biocueing may have in augmenting existing treatments, especially in increasing interoceptive sensibility, for patients with BPD.

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**Table 1***Demographic data of participants (N=9)*

<b>Variable</b>		<b>Number (%)</b>
Highest completed education level	Secondary education	2 (22%)
	Secondary vocational education	5 (56%)
	Higher education	2 (22%)
Comorbidity	Depressive disorder	5 (56%)
	Substance use disorder	3 (33%)
	ADHD	2 (22%)
	Avoidant personality disorder	2 (22%)

**Table 2**

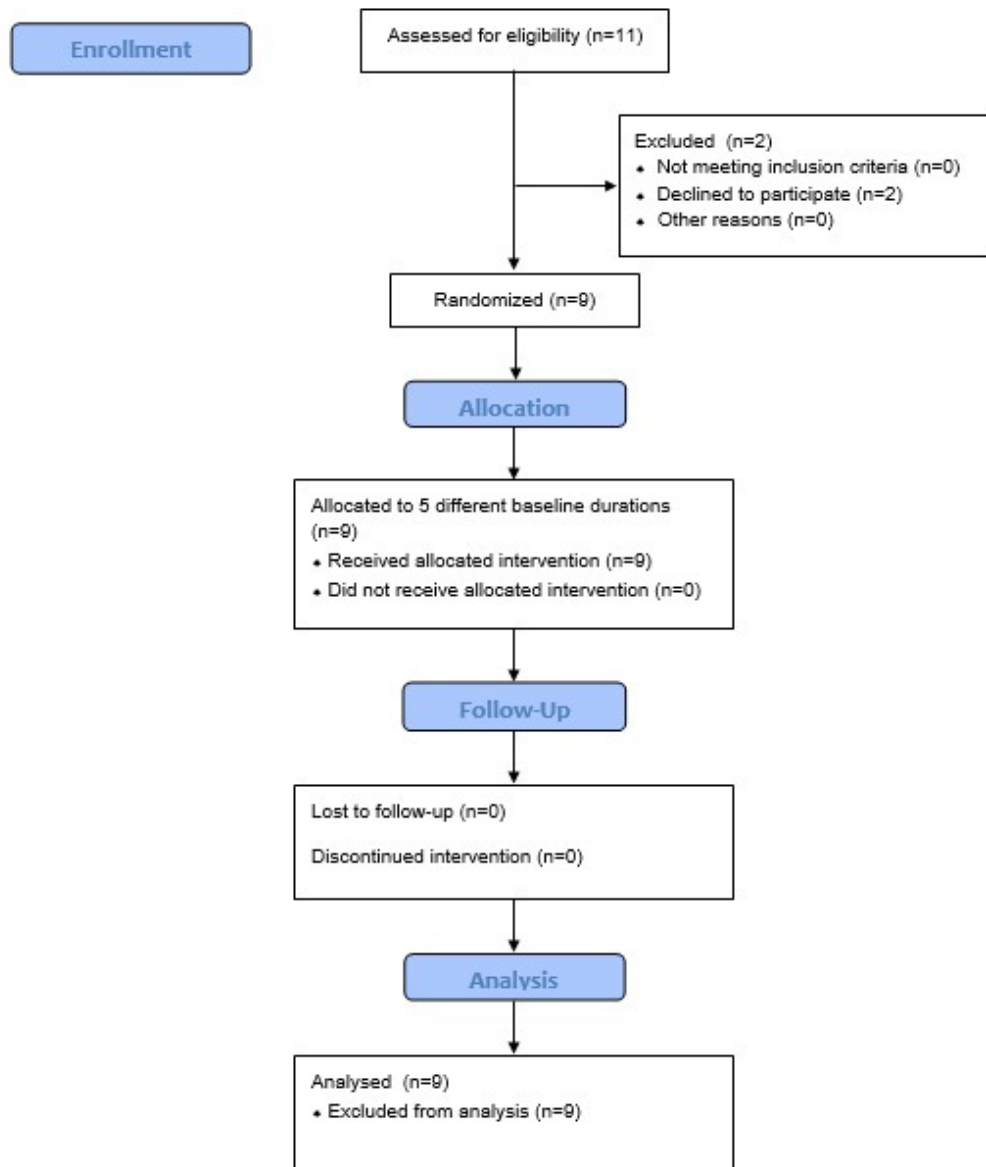
*Reliable change analyses*

		<b>End of intervention phase</b>	<b>End of follow-up phase</b>
MAIA-2 <sup>a</sup>	Reliable improved	0%	11%
	Unchanged	100%	89%
	Reliable deteriorated	0%	0%
DERS-18 <sup>b</sup>	Reliable improved	0%	0%
	Unchanged	67%	89%
	Reliable deteriorated	33%	11%

<sup>a</sup> Multidimensional Assessment Interoceptive Awareness-2. <sup>b</sup> Difficulties in Emotion Regulation Scale-18

**Figure 1**

*CONSORT Flow diagram*



**Figure 2**

*Daily measurement of body awareness, with indicated number of weeks DBT*

