Cranial Electrotherapy Stimulation as an Aid for Relaxation, Stress Relief, Mood Improvement and Improving Sleep Quality

Christopher D. James 27 November 2014

Summary

Objective: The aim of this study was to determine if cranial electrotherapy stimulation (CES) is an effective aid for relaxation, stress relief, mood improvement and improving sleep quality.

Methods: The pilot study used an uncontrolled, open-label approach with a before/after questionnaire to measure any improvement.

Results: The percentage overall change (sum of change / maximum potential beneficial change) per category was observed as follows: Sleep +56% (76/135), Relaxation +35% (45/130), Stress +28% (35/126), Mood +20% (18/91).

Conclusions: The volunteers reported a significant improvement in sleep quality. Benefits were also observed in the other three categories of relaxation, stress relief and mood improvement. These results are similar to results from other studies of the technology. There is a need for a double-blind study of this device at the settings used in this study, and also at other settings.

Key Words: *Cranial electrotherapy stimulation, CES, mood, relaxation, sleep, stress.*

Introduction

Cranial Electrotherapy Stimulation (CES) is a method of non-invasive brain stimulation that applies a small, pulsed alternating electric current across a user's head. Previous studies have almost solely focused on the clinical use of CES for the treatment of anxiety, depression, insomnia and chronic pain.[1] This study, whilst including some subjects with diagnosed medical conditions, also included subjects with no significant medical complaints. The CES device used in this study was the Hushe A-CES® ("the device")[2].

Objective

The aim of this study was to test whether use of the device is effective in the promotion of any or all of the following:

i. relaxation;
ii. stress relief;
iii. mood improvement; and
iv. improving sleep quality.

As this was the first study involving this particular CES device, the intention was to measure any base-line subjective effects that may have resulted from using the device in the manner described in the manufacturer's instructions.[3] It is hoped that the results of this initial study may provide a basis from which to proceed with the design and scaling of future blind and/or double-blind studies involving this device by reference to the size of the effects that were observed in this study.

Methods

The study initially consisted of nine adult volunteers, each of whom was given a unique identification code to anonymise the data. Two volunteers were excluded from the study: one was taking multiple medications and experienced neurological symptoms (see "Reported side effects") and the other did not actually use the device. The average age of the final seven participants was 56.4 years. Five were female.

Changes in the four areas under examination (relaxation, stress, mood and sleep) were recorded using a before and after online web-form statement response questionnaire. Through this system, both before and after using the device, volunteers responded to 8 statements relating to each of the four areas, making a total of 32 statements. Volunteers were asked to indicate how much each statement applied to them on a scale from 1 to 5, with 1 corresponding to "Not at all" and 5 to "Absolutely. The statements presented to the volunteers are listed alongside the summary of results below, and in the Appendix. The coding used was not presented to the volunteers and is used in this paper for ease of reference.

The statements are distributed roughly 50:50 as regards *positive* vs. *negative* statements. This was considered important in order to reduce any tendency for answers to trend in relation to previous answers. Whilst on the most part it should be obvious which statements are positive and which are negative indicators for each area, the division of each is shown by the following table:

Positive statements	Negative statements
RE1, RE3, RE4, RE7, RE8	RE2, RE5, RE6
ST2, ST5, ST6, ST8	ST1, ST3, ST4, ST7
MD2, MD4, MD5, MD7	MD1, MD3, MD6, MD8
SL3, SL4, SL5, SL8	SL1, SL2, SL6, SL7

For *positive statements*, an *increase* in value after using the device may be considered as evidence suggesting that using the device caused a beneficial change in the

volunteer. In contrast, for *negative statements*, a *decrease* in value after using the device may be considered as evidence suggesting that using the device caused a beneficial change in the volunteer. Therefore the analysis of results must take into account the nature of each statement and invert any change in the response to *negative* statements in order to obtain an overall indicator of beneficial effect.

A 'general comments' section was also provided on the web-form questionnaire for volunteers to add any particular comments they felt may be of interest. Upon submission, the contents of the web-form questionnaires were automatically e-mailed to the study administrator including the volunteer's IP address, date and time of completion.

Between questionnaires, volunteers used the device for two weeks, twice per day for 25 minutes per session. The device was set at a frequency of 0.5 Hz using a square-split waveform and a duty cycle of 50%.

Results

The raw data are provided in the Appendix at the end of this article. The results can be summarised in the following general statements, which provide a summary of the overall change within the group. Given the small sample size, the group percentages are approximated to the nearest 5%. Each result is accompanied by the percentage measure of the observed change across the group.

Of the seven participants, after using the device:

Relaxation

RE1: *"I find it easy to relax."*
- **70%** felt more like they find it easy to relax;
- **15%** felt no change here;
- **15%** felt less like they find it easy to relax.
- The overall change was +37% (7/19).

RE2: *"My muscles are often tense."*
- **70%** felt less like their muscles are often tense;
- 0% felt no change here;
- **30%** felt more like their muscles are often tense.
- The overall change was +33% (6/18).

RE3: *"I find it easy to quiet my mind."*
- **55%** felt more like they find it easy to quiet their mind;
- **30%** felt no change here;
- **15%** felt less like they find it easy to quiet their mind.
- The overall change was +44% (8/18).

RE4: *"I often lose my sense of physical space."*
- **40%** felt more like they often lose their sense of physical space;
- **30%** felt no change here;
- **30%** felt less like they often lose their sense of physical space.
- The overall change was +5% (1/20).

RE5: *"I find it hard to control my breathing."*
- **45%** felt less like they find it hard to control their breathing;
- **55%** felt no change here;
- 0% felt more like they find it hard to control their breathing.
- The overall change was +40% (4/10).

RE6: *"My limbs often feel numb."*
- **30%** felt less like their limbs often feel numb;
- **55%** felt no change here;
- **15%** felt more like their limbs often feel numb.
- The overall change was +33% (2/6).

RE7: *"My thoughts remain quiet and not disturbing."*
- **55%** felt more like their thoughts remain quiet and not disturbing;
- **15%** felt no change here;
- **30%** felt less like their thoughts remain quiet and not disturbing.
- The overall change was +40% (8/20).

RE8: *"I find it easy to ignore external noises."*
- **70%** felt more like they find it easy to ignore external noises;
- **30%** felt no change here;
- 0% felt less like they find it easy to ignore external noises.
- The overall change was +47% (9/19).

Stress

ST1: *"I am easily stressed."*
- **55%** felt less like they are easily stressed;
- **45%** felt no change here;
- 0% felt more like they are easily stressed.
- The overall change was +44% (8/18).

ST2: *"I never lose my temper."*
- **40%** felt more like they never lose their temper;
- **30%** felt no change here;
- **30%** felt less like they never lose their temper.
- The overall change was 0% (0/19).

ST3: *"I get headaches due to stress."*
- **45%** felt less like they get headaches due to stress;
- **55%** felt no change here;
- 0% felt more like they get headaches due to stress.
- The overall change was +38% (5/13).

ST4: *"I often feel tired with no energy."*
- **70%** felt less like they often feel tired with no energy;
- **15%** felt no change here;
- **15%** felt more like they often feel tired with no energy.
- The overall change was +35% (8/23).

ST5: *"I rarely get annoyed with other people."*
- **85%** felt more like they rarely get annoyed with other people;
- 0% felt no change here;
- **15%** felt less like they rarely get annoyed with other people.
- The overall change was +27% (6/22).

ST6: *"I am satisfied with my life."*
- **30%** felt more like they are satisfied with their life;
- **55%** felt no change here;
- **15%** felt less like they are satisfied with their life.
- The overall change was +22% (2/9).

ST7: *"I experience difficult relationships with people."*
- **45%** felt less like they experience difficult relationships with people;
- **45%** felt no change here;
- **10%** felt more like they experience difficult relationships with people.
- The overall change was +40% (4/10).

ST8: *"I smile a lot."*
- **30%** felt more like they smiled a lot;
- **55%** felt no change here;
- **15%** felt less like they smiled a lot.
- The overall change was +17% (2/12).

Mood

MD1: *"I often feel sad or unhappy."*
- **30%** felt less like they often feel sad or unhappy;
- **70%** felt no change here;
- 0% felt more like they often feel sad or unhappy.
- The overall change was +21% (3/14).

MD2: *"I enjoy most things that I do."*
- **45%** felt more like they enjoy most things that they do;
- **55%** felt no change here;
- 0% felt less like they enjoy most things that they do.
- The overall change was +44% (4/9).

MD3: *"I often just sit around doing nothing."*
- **15%** felt less like they often just sit around doing nothing;
- **55%** felt no change here;
- **30%** felt more like they often just sit around doing nothing.
- The overall change was -17% (-1/6).

MD4: *"I am never restless."*
- **40%** felt more like they are never restless;
- **30%** felt no change here;
- **30%** felt less like they are never restless.
- The overall change was +11% (2/18).

MD5: *"I feel like a good person."*
- **45%** felt more like a good person;
- **55%** felt no change here;
- 0% felt less like a good person.
- The overall benefit was +36% (4/11).

MD6: *"I tend to cry a lot."*
- **15%** felt less like they tend to cry a lot;
- **70%** felt no change here;
- **15%** felt more like they tend to cry a lot.
- The overall change was -17% (-1/6).

MD7: *"I never feel lonely."*
- **70%** felt more like they never feel lonely;
- **15%** felt no change here;
- **15%** felt less like they never feel lonely.
- The overall change was +25% (4/16).

MD8: *"I do everything wrong."*
- **45%** felt less like they do everything wrong;
- **45%** felt no change here;
- **10%** felt more like they do everything wrong.
- The overall change was +27% (3/11).

Sleep

SL1: *"I have difficulty falling asleep."*
- **70%** felt less like they have difficulty falling asleep;
- **30%** felt no change here;
- 0% felt more like they have difficulty falling asleep.
- The overall change was +80% (12/15).

SL2: *"My thoughts prevent me from falling asleep."*
- **85%** felt less like their thoughts prevented them from falling asleep;
- **15%** felt no change here;
- 0% felt more like their thoughts prevented them from falling asleep.
- The overall change was +79% (15/19).

SL3: *"I look forward to going to sleep."*
- **45%** felt more like they look forward to going to sleep;
- **45%** felt no change here;
- **10%** felt less like they look forward to going to sleep.
- The overall change was +25% (2/8).

SL4: *"I usually sleep right through the night."*
- **45%** felt more like they usually sleep right through the night;
- **45%** felt no change here;
- **10%** felt less like they usually sleep right through the night.
- The overall change was +30% (6/20).

SL5: *"I feel refreshed after a night's sleep."*
- **70%** felt more refreshed after a night's sleep;
- **30%** felt no change here;
- 0% felt less refreshed after a night's sleep.
- The overall change was +50% (10/20).

SL6: *"I tend to wake up earlier than I would like to."*
- **70%** felt less that they tended to wake up earlier than they would like to;
- **30%** felt no change here;
- 0% felt more that they tended to wake up earlier than they would like to.
- The overall change was +58% (11/19).

SL7: *"It usually takes 30 minutes or more for me to fall asleep."*
- **70%** felt less like it usually takes 30 minutes or more for them to fall asleep;
- **30%** felt no change here;
- 0% felt more like it usually takes 30 minutes or more for them to fall asleep.
- The overall change was +93% (14/15).

SL8: *"My body feels good when I wake up."*
- **70%** felt more like their body feels good when they wake up;
- **15%** felt no change here;
- **15%** felt less like their body feels good when they wake up.
- The overall change was +32% (6/19).

Sum of change

The table below shows the "Sum" values from the tables in the Appendix, sorted in descending order. The smaller the absolute magnitude of the value, the less likely it is that the effect is real and not just a product of random variation in subjective experiences during the study period. By contrast, the larger the absolute magnitude of the value, the more likely it is that the effect is real, whether placebo or actual.

Code	Statement	Sum of change
SL2	My thoughts prevent me falling asleep	15
SL7	Usually takes ≥30 min to fall asleep	14
SL1	I have difficulty falling asleep	12
SL6	I tend to wake earlier than I would like	11
SL5	I feel refreshed after a night's sleep	10
RE8	I find it easy to ignore external noises	9
RE3	I find it easy to quiet my mind	8
RE7	Thoughts remain quiet / not disturbing	8
ST1	I am easily stressed	8
ST4	I often feel tired with no energy	8
RE1	I find it easy to relax	7
RE2	My muscles are often tense	6
SL4	I usually sleep right through the night	6
SL8	My body feels good when I wake up	6
ST5	I rarely get annoyed with other people	6
ST3	I get headaches due to stress	5
MD2	I enjoy most things that I do	4
MD5	I feel like a good person	4
MD7	I never feel lonely	4
RE5	I find it hard to control my breathing	4
ST7	I experience diff. relationships w. people	4
MD1	I often feel sad or unhappy	3
MD8	I do everything wrong	3
MD4	I am never restless	2
RE6	My limbs often feel numb	2
SL3	I look forward to going to sleep	2
ST6	I am satisfied with my life	2
ST8	I smile a lot	2
RE4	I often lose my sense of physical space	1
ST2	I never lose my temper	0
MD3	I often just sit around doing nothing	-1
MD6	I tend to cry a lot	-1

Change as a percentage of maximum possible change

The table below shows the changes as a percentage of maximum possible beneficial change, sorted in descending order.

Code	Statement	% Max (Sum/Max)
SL7	Usually takes ≥30 min to fall asleep	93%
SL1	I have difficulty falling asleep	80%
SL2	My thoughts prevent me falling asleep	79%
SL6	I tend to wake earlier than I would like	58%
SL5	I feel refreshed after a night's sleep	50%
RE8	I find it easy to ignore external noises	47%
RE3	I find it easy to quiet my mind	44%
ST1	I am easily stressed	44%
MD2	I enjoy most things that I do	44%
RE7	Thoughts remain quiet / not disturbing	40%
RE5	I find it hard to control my breathing	40%
ST7	I experience diff. relationships w. people	40%
ST3	I get headaches due to stress	38%
RE1	I find it easy to relax	37%
MD5	I feel like a good person	36%
ST4	I often feel tired with no energy	35%
RE2	My muscles are often tense	33%
RE6	My limbs often feel numb	33%
SL8	My body feels good when I wake up	32%
SL4	I usually sleep right through the night	30%
ST5	I rarely get annoyed with other people	27%
MD8	I do everything wrong	27%
MD7	I never feel lonely	25%
SL3	I look forward to going to sleep	25%
ST6	I am satisfied with my life	22%
MD1	I often feel sad or unhappy	21%
ST8	I smile a lot	17%
MD4	I am never restless	11%
RE4	I often lose my sense of physical space	5%
ST2	I never lose my temper	0%
MD3	I often just sit around doing nothing	-17%
MD6	I tend to cry a lot	-17%

Average overall change per category

The percentage change (sum of change / maximum potential beneficial change) per statement can be combined by category to achieve an indicator of overall change in each category as a whole, as shown below in descending order:

Category	Change %	Values
Sleep (SL)	+56%	76/135
Relaxation (RE)	+35%	45/130
Stress (ST)	+28%	35/126
Mood (MD)	+20%	18/91

Participant commentaries

The comments section of the questionnaire allowed each volunteer to provide any comments before using the device, and they were specifically asked for comments about their experience after having used the device. The responses received are provided below, together with the gender, age and identifier for cross reference with the results table above. "N/A" indicates that no comment was provided. Some of the comments have been edited for grammatical purposes, personally identifying information and relevance.

Female, 56 years (ID 1)

Before: N/A
After: *"When I started this I had no idea I would be rapidly put under extreme pressure from external sources. Usually these would have brought me crashing down but to my surprise and interest I feel I coped much better than I would ever have expected myself to! ... I experienced some light headedness at the start of each session but this gradually went."*

Female, 54 years (ID 2)

Before: N/A
After: *"My quality of sleep has improved immensely and I have no difficulty falling asleep at the moment. I also feel better when I wake. I have found that I don't get irritated so easily either. This has been a positive experience."*

Male, 62 years (ID 3)

Before: N/A
After: *"External events beyond my control during the trial may mean that my answers may have been skewed. I found there was a difference in the level that I needed to go down one between evening and morning usage. I also think that the level was affected by my stress level caused by external pressures. The baseline measurements could well have been affected by this. Feedback from others suggests that I was less irritable than before. However this may have been as a result of external circumstances. I do think that I slept better and the incidences of night cramps may have reduced due to me being less restless..."*

Female, 69 years (ID 4)

Before: *"[I find it] not too bad falling asleep initially but wake up several times and then find it very hard to get back to sleep."*
After: *"Bizarrely I found it stressful hooking up and using it! I found it hard to set it at the best level for me and sometimes felt nauseous. I was lightheaded most [of the] time when I used it."*

Editor's comment: It is interesting to note that although this volunteer may have been in the minority in not enjoying the experience, the questionnaire responses show a net improvement of +13/27 points in the sleep category with no disbenefit and a net improvement across other categories of +6 points with only two instances of -1 changes.

Male, 62 years (ID 5)

Before: *"I consider that I use stress as a method to 'get the job done' at work, which is an addictive spiral. ... [I am] currently stopping this habit after advice from [my] psychotherapist. Sleep is more of a 'passing out' currently, so [I fall] asleep within say 30 seconds or less. Sometimes [I have] too busy a mind to relax so I either fidget or get on with some task. Occasionally this occurs during sleep when I wake up and my mind is fixated on some issue, thus stopping me [from going] into a sleep mode [of] thinking. ..."*
After: *"The most noticeable change in my mood/sleep after using the A-CES is that after a week I was experiencing or at least being very aware of dreaming during sleep. I know that during periods of stress at work I am not aware of dreaming during sleep. Interestingly, some 10+ years ago [I was] diagnosed with depression [and] put on antidepressants. One of [the] more interesting side effects was the very vivid dreams I had during sleep. During my period of using [the] A-CES life for me has been very variable in terms of both work and home life (stress ups and downs). Therefore it is difficult to identify personal changes. For example, I have had a period of virtually no work for about three days, a new experience for me and stressful but I coped well. Whether this is normal for me or [if it] helped [using the] A-CES, [is] hard to tell. On the whole, considering the stresses of the last month, work and building work at home, I have coped very well. So I have to say there have been some very positive aspects to my usage of [the] A-CES. Equally, [committing textual information to memory has been a lot easier than previously.]"*

Female, 61 years (ID 6)

Before: *"I find physical activity can relax me, [such as] a good walk, gardening or swimming, etc. I suffer from stress related headaches and find visiting a good friend or talking to them on the phone about general things helps to reduce the headache. I often fall asleep then wake soon after and then struggle to get back to sleep. On occasion I get up in the night [but am] unable to get back to sleep and find [that] writing down my feelings about a situation that is worrying helps to clear the problem away in order to 'allow' me to get back to sleep. A ceiling fan has helped with room temperature at night and the quiet motor noise can feel calming."*
After: *"I have noticed that I am sleeping better and even if I wake up in the night I have been able to get back to sleep far more readily. I have also been dreaming far more than in recent times. As a consequence I have been more prepared to try to get back to sleep especially if I'm awake just a bit too early rather than seeing it as a hopeless thing to attempt. Whether it is because I am sleeping in a different way I'm not sure but I don't seem to have woken up with a pins and needles numbness going on in my arm. ... I did actually sleep right through one night which I have not done for years."*

Female, 27 years (ID 7)

Before: N/A
After: *"This device really helped me. Mainly with my sleep which I feel had a knock on affect with everything else. I would recommend it to anyone that has trouble sleeping, gets in to moods easily, stressed out or not relaxed. Thanks so much for letting me take part."*

Reported side effects

One of the preliminary volunteers was a 69 year old male taking three drugs (the hypolipidemic Simvastatin, the angiotensin-converting enzyme inhibitor Lisinopril and the noradrenergic and specific serotonergic antidepressant Mirtazapine). He reported that even at the lowest output level on the device there was an experience of tingling sensations in the face, right arm and lower leg and so he decided to withdraw from the study. Side effects such as these have not previously been reported by users of the Hushe A-CES, nor by users of other CES devices.[4]

Two users reported experiencing light-headedness and/or mild nausea whilst using the device.

Other reported side effects were increased dreaming and improved verbal memory,

Commentary

Referring first to the existing research in the field of CES, a useful point of reference was published in 2007 in the form of five meta-analyses that were computed to summarise most of the studies of CES appearing in the U.S. scientific literature.[5] The five areas studied in that work were Insomnia, Depression, Anxiety, Drug Abstinence and Cognitive Dysfunction, the first three of which are related to the present study (Insomnia to Sleep, Depression to Mood, Anxiety to Relaxation/Stress). A summary of the meta-analyses is provided in the table below:

Syndrome Studied	No. of Studies	No. of Subjects	Average Improvement
Insomnia	18	648	62%
Anxiety	38	1495	58%
Depression	18	853	47%

When looked at alongside the results of the present pilot study, a similar ordering of average improvement can be shown. The present study did not target subjects with complaints specific to any particular area under study in contrast with the targeted studies analysed in the reference material. As such, it is not surprising that the average improvement in this study should be lower than that observed in the targeted studies, as shown in the following table:

Meta-analyses Category	Meta-analyses Avg. Improv.	Present Study Comparison	Present Study Avg. Improv.
Insomnia	62%	Sleep	56%
Anxiety	58%	Relaxation / Stress	35% / 28%
Depression	47%	Mood	20%

No placebo effect in CES treatment has ever been found when that effect was specifically controlled for, with the possible exception of a negative placebo effect that one study found in non-treated patients. [6]

This was a small, open-label pilot study that was intended to guide future research in a double-blind fashion. It did not target any specific disorder or complaint and involved subjects with a range of backgrounds who did not necessarily have any complaints in the areas under examination.

All categories demonstrated an overall improvement. The greatest changes were seen in the sleep (SL) category of statements, with an average change of +56% (76/135) of the maximum possible beneficial change. Within the sleep category, the strongest performing statements were those that related to falling asleep (SL7, SL1, SL2).

I would think it to be very likely that "improving sleep quality" should be a priority outcome in any future study at these device settings. Remarkably, the only 'negatively beneficial' changes that were observed in the sleep category were from volunteer ID 3 who reported that *"external events beyond [his] control during the trial may mean that [his] answers may have been skewed"* (see "Participant commentaries").

The second category by magnitude of change was relaxation (RE) with an average change of +35% (45/130) of the maximum possible beneficial change. Within the relaxation category, the strongest performing statements were those that related to the ability to ignore unwelcome distractions, both external and internal, what I might phrase as "peace of mind" statements (RE8, RE3, RE7, RE1).

The third-most category by degree of change was the one relating to stress (ST), with an average change of +28% (35/126) of the maximum possible beneficial change. The strongest performing statements within the stress category were those that dealt with the perception of how easily one is stressed (ST1) and lack of energy (ST4), the latter arguably crossing over with the sleep category.

The final category was the mood (MD) category, with an average change of +20% (18/91). Of this category, the greatest changes were observed in the areas relating to enjoyment of daily activities (MD2) and self-image (MD5, MD8).

Interestingly, the performance of each category inversely matches its order in respect of the maximum potential beneficial change (Sleep = 135, Relaxation = 130, Stress = 126, Mood = 91). This would suggest that the subjects involved in this study were most similar to subjects involved in the meta-analyses work[5] on Insomnia, which could explain why the Sleep category most closely matches the meta-analyses.

Of the negative results (MD3 & MD6), the small sample size means that little weight can be placed on these values and they are best treated as noise for the time being. This of course also applies to positive changes of similarly low magnitude (e.g. ST8, MD4, RE4, ST2).

Possible explanation of effects

Given the strength of the results for sleep, it is appropriate here to focus mainly on the way in which the Hushe A-CES may cause an improvement to the user's quality of sleep.

The frequency used was 0.5 Hz, which sits within the region occupied by delta waves in the brain (0.5 – 2 Hz)[7]. These waves are present in stage N3 slow-wave sleep, a stage of sleep that is considered to be important for the consolidation of new memories.[8] Sleep deprivation studies indicate that the main function of slow-wave sleep may be to allow the brain to recover from its daily activities.[9] A lack of slow-wave sleep can induce waking stress and consequently impact on the mood and sense of relaxation.

Slow-wave sleep is also thought to be responsible for a decrease in sympathetic and increase in parasympathetic neural activity.[10] Parasympathetic activity is responsible for stimulating activities that are associated with the body at rest. This is in contrast to the sympathetic nervous system, which regulates the fight-or-flight response.

The 0.5 Hz frequency of the Hushe A-CES may somehow be inducing a waking-form of slow-wave sleep, or facilitating the transition to slow-wave sleep more readily when it is time for bed. This could be confirmed with an EEG connected to the user of the device, and could be the subject of a future study.

If indeed the parasympathetic nervous system is being stimulated and the sympathetic nervous system inhibited by the simulated delta-waves, this would go some way to explaining the accompanying increased sense of relaxation and reduced of stress, all of which may go some way to improving the user's mood, or overall sense of wellbeing.

Conclusion

In conclusion, the volunteers reported a significant improvement in sleep quality. Benefits were also observed in the other three categories of relaxation, stress relief and mood improvement. There is a need for a double-blind study of this device at the settings used in this study, and also at other settings. Of particular interest should be the frequency used in the study. This study used a 0.5 Hz frequency, square split waveform. The device used in this study is also capable of generating 50 Hz and 100Hz frequencies, and can easily be customised with updated firmware to produce a linear range of frequencies at increments of 0.1 Hz if required.

Conflict of interest statement

The device used in this study, the Hushe A-CES®, was designed by Christopher D. James.

Appendix – Raw data tables

The raw data from the questionnaires are shown in the following 32 tables. Each table shows the responses of all participants to a particular statement. The "ID" column refers to the participant ID and can be used to cross-reference with the section "Participant commentaries" in the main article. For *positive* statements, the "**Change P**" is calculated as "After minus Before". For *negative* statements, the "**Change N**" is calculated as "Before minus After". Using this approach achieves a consistent visual representation of the magnitude of "Change", with bars extending to the right of the origin indicating a possible benefit and bars to the left of the origin indicating a possible disbenefit.

The column "Max" indicates the maximum possible beneficial change that could be achieved, given each volunteer's "Before" response. It assumes that for positive and negative statements, the maximum benefit would be suggested with an "After" response of 5 and 1 respectively. So for example, for a positive statement where a volunteer submitted a "Before" response of 2, the "Max" would be 3 (= 5 – 2). If that statement had conversely been negative, the "Max" would be 1 (= 2 – 1). The sums of "Change" and "Max" can then be combined in Change / Max = "% Max", an indicator of the strength of the observed changes. This percentage is shown in parentheses after the sum of the change.

Relaxation

RE1: ***I find it easy to relax.*** (Positive)

ID	Before	After	Change P	Max
1	1	3	2	4
2	2	3	1	3
3*	4	3	-1	1
4	2	2	0	3
5	3	4	1	2
6	3	4	1	2
7	1	4	3	4
Sum (% Max)			**7 (37%)**	19

* Cf. the "Participant commentaries" entry for this participant.

RE2: ***My muscles are often tense.*** (Negative)

ID	Before	After	Change N	Max
1	4	3	1	3
2	5	3	2	4
3*	2	3	-1	1
4	4	3	1	3
5	4	2	2	3
6	1	3	-2	0
7	5	2	3	4
Sum (% Max)			**6 (33%)**	18

RE3: ***I find it easy to quiet my mind.*** (Positive)

ID	Before	After	Change P	Max
1	1	3	2	4
2	1	4	3	4
3*	5	5	0	0
4	2	1	-1	3
5	4	4	0	1
6	3	4	1	2
7	1	4	3	4
Sum (% Max)			**8 (44%)**	18

RE4: ***I often lose my sense of physical space.***[4] (Positive)

ID	Before	After	Change P	Max
1	2	1	-1	3
2	2	3	1	3
3*	1	2	1	4
4	3	3	0	2
5	3	4	1	2
6	1	1	0	4
7	3	2	-1	2
Sum (% Max)			**1 (5%)**	20

RE5: ***I find it hard to control my breathing.*** (Negative)

ID	Before	After	Change N	Max
1	2	2	0	1
2	3	3	0	2
3*	1	1	0	0
4	4	3	1	3
5	3	1	2	2
6	1	1	0	0
7	3	2	1	2
Sum (% Max)			**4 (40%)**	10

RE6: ***My limbs often feel numb.*** (Negative)

ID	Before	After	Change N	Max
1	2	2	0	1
2	1	1	0	0
3*	2	2	0	1
4	2	1	1	1
5	4	2	2	3
6	1	1	0	0
7	1	2	-1	0
Sum (% Max)			**2 (33%)**	6

RE7: ***My thoughts remain quiet and not disturbing.*** (Positive)

ID	Before	After	**Change P**	Max
1	1	3	2	4
2	1	4	3	4
3*	4	3	-1	1
4	1	3	2	4
5	3	2	-1	2
6	4	4	0	1
7	1	4	3	4
Sum (% Max)			**8 (40%)**	20

RE8: ***I find it easy to ignore external noises.*** (Positive)

ID	Before	After	**Change P**	Max
1	1	3	2	4
2	1	3	2	4
3*	5	5	0	0
4	3	3	0	2
5	3	4	1	2
6	2	3	1	3
7	1	4	3	4
Sum (% Max)			**9 (47%)**	19

Stress

ST1: ***I am easily stressed.*** (Negative)

ID	Before	After	**Change N**	Max
1	4	3	1	3
2	4	2	2	3
3*	2	2	0	1
4	4	4	0	3
5	4	3	1	3
6	2	2	0	1
7	5	1	4	4
Sum (% Max)			**8 (44%)**	18

ST2: ***I never lose my temper.*** (Positive)

ID	Before	After	**Change P**	Max
1	2	2	0	3
2	3	4	1	2
3*	3	2	-1	2
4	2	2	0	3
5	1	2	1	4
6	4	2	-2	1
7	1	2	1	4
Sum (% Max)			**0 (0%)**	19

ST3: ***I get headaches due to stress.*** (Negative)

ID	Before	After	**Change N**	Max
1	1	1	0	0
2	4	2	2	3
3*	2	2	0	1
4	2	2	0	1
5	5	4	1	4
6	5	3	2	4
7	1	1	0	0
Sum (% Max)			**5 (38%)**	13

ST4: ***I often feel tired with no energy.*** (Negative)

ID	Before	After	**Change N**	Max
1	5	4	1	4
2	5	2	3	4
3*	2	3	-1	1
4	5	4	1	4
5	5	4	1	4
6	3	3	0	2
7	5	2	3	4
Sum (% Max)			**8 (35%)**	23

ST5: ***I rarely get annoyed with other people.*** (Positive)

ID	Before	After	**Change P**	Max
1	2	3	1	3
2	2	3	1	3
3*	3	2	-1	2
4	2	3	1	3
5	1	2	1	4
6	2	4	2	3
7	1	2	1	4
Sum (% Max)			**6 (27%)**	22

ST6: ***I am satisfied with my life.*** (Positive)

ID	Before	After	**Change P**	Max
1	3	3	0	2
2	3	4	1	2
3*	4	4	0	1
4	3	2	-1	2
5	5	5	0	0
6	5	5	0	0
7	3	5	2	2
Sum (% Max)			**2 (22%)**	9

ST7: ***I experience difficult relationships with people.*** (Negative)

ID	Before	After	**Change N**	Max
1	3	2	1	2
2	2	3	-1	1
3*	1	1	0	0
4	3	3	0	2
5	3	1	2	2
6	1	1	0	0
7	4	2	2	3
Sum (% Max)			**4 (40%)**	10

MD3: ***I often just sit around doing nothing.*** (Negative)

ID	Before	After	**Change N**	Max
1	2	3	-1	1
2	1	2	-1	0
3*	3	2	1	2
4	3	3	0	2
5	1	1	0	0
6	1	1	0	0
7	2	2	0	1
Sum (% Max)			**-1 (-17%)**	6

ST8: ***I smile a lot.*** (Positive)

ID	Before	After	**Change P**	Max
1	2	2	0	3
2	2	3	1	3
3*	4	3	-1	1
4	3	3	0	2
5	3	5	2	2
6	4	4	0	1
7	5	5	0	0
Sum (% Max)			**2 (17%)**	12

MD4: ***I am never restless.*** (Positive)

ID	Before	After	**Change P**	Max
1	3	4	1	2
2	2	3	1	3
3*	2	2	0	3
4	2	2	0	3
5	2	1	-1	3
6	5	3	-2	0
7	1	4	3	4
Sum (% Max)			**2 (11%)**	18

Mood

MD1: ***I often feel sad or unhappy.*** (Negative)

ID	Before	After	**Change N**	Max
1	3	3	0	2
2	2	2	0	1
3*	2	2	0	1
4	5	5	0	4
5	3	2	1	2
6	2	2	0	1
7	4	2	2	3
Sum (% Max)			**3 (21%)**	14

MD5: ***I feel like a good person.*** (Positive)

ID	Before	After	**Change P**	Max
1	2	4	2	3
2	3	3	0	2
3*	4	4	0	1
4	3	3	0	2
5	4	5	1	1
6	5	5	0	0
7	3	4	1	2
Sum (% Max)			**4 (36%)**	11

MD2: ***I enjoy most things that I do.*** (Positive)

ID	Before	After	**Change P**	Max
1	1	3	2	4
2	4	4	0	1
3*	5	5	0	0
4	4	4	0	1
5	4	5	1	1
6	5	5	0	0
7	3	4	1	2
Sum (% Max)			**4 (44%)**	9

MD6: ***I tend to cry a lot.*** (Negative)

ID	Before	After	**Change N**	Max
1	1	1	0	0
2	2	2	0	1
3*	1	1	0	0
4	3	3	0	2
5	2	1	1	1
6	2	2	0	1
7	2	4	-2	1
Sum (% Max)			**-1 (-17%)**	6

MD7: ***I never feel lonely.*** (Positive)

ID	Before	After	**Change P**	Max
1	2	3	1	3
2	2	3	1	3
3*	4	5	1	1
4	1	2	1	4
5	4	1	-3	1
6	5	5	0	0
7	1	4	3	4
Sum (% Max)			**4 (25%)**	16

SL3: ***I look forward to going to sleep.*** (Positive)

ID	Before	After	**Change P**	Max
1	5	5	0	0
2	4	5	1	1
3*	4	2	-2	1
4	1	3	2	4
5	5	5	0	0
6	3	4	1	2
7	5	5	0	0
Sum (% Max)			**2 (25%)**	8

MD8: ***I do everything wrong.*** (Negative)

ID	Before	After	**Change N**	Max
1	4	2	2	3
2	2	2	0	1
3*	2	1	1	1
4	4	4	0	3
5	2	1	1	1
6	1	1	0	0
7	3	4	-1	2
Sum (% Max)			**3 (27%)**	11

SL4: ***I usually sleep right through the night.*** (Positive)

ID	Before	After	**Change P**	Max
1	3	3	0	2
2	1	4	3	4
3*	2	1	-1	3
4	1	1	0	4
5	4	4	0	1
6	2	4	2	3
7	2	4	2	3
Sum (% Max)			**6 (30%)**	20

Sleep

SL1: ***I have difficulty falling asleep.*** (Negative)

ID	Before	After	**Change N**	Max
1	4	2	2	3
2	3	1	2	2
3*	1	1	0	0
4	4	1	3	3
5	1	1	0	0
6	4	2	2	3
7	5	2	3	4
Sum (% Max)			**12 (80%)**	15

SL5: ***I feel refreshed after a night's sleep.*** (Positive)

ID	Before	After	**Change P**	Max
1	1	2	1	4
2	2	4	2	3
3*	3	3	0	2
4	2	2	0	3
5	3	5	2	2
6	3	4	1	2
7	1	5	4	4
Sum (% Max)			**10 (50%)**	20

SL2: ***My thoughts prevent me from falling asleep.*** (Negative)

ID	Before	After	**Change N**	Max
1	4	2	2	3
2	4	2	2	3
3*	1	1	0	0
4	4	1	3	3
5	4	2	2	3
6	4	2	2	3
7	5	1	4	4
Sum (% Max)			**15 (79%)**	19

SL6: ***I tend to wake up earlier than I would like to.*** (Negative)

ID	Before	After	**Change N**	Max
1	3	2	1	2
2	4	1	3	3
3*	1	1	0	0
4	5	3	2	4
5	4	2	2	3
6	4	4	0	3
7	5	2	3	4
Sum (% Max)			**11 (58%)**	19

SL7: ***It usually takes 30 minutes or more for me to fall asleep.*** (Negative)

ID	Before	After	**Change N**	Max
1	4	2	2	3
2	4	1	3	3
3*	1	1	0	0
4	4	1	3	3
5	1	1	0	0
6	3	1	2	2
7	5	1	4	4
Sum (% Max)			**14 (93%)**	15

SL8: ***My body feels good when I wake up.*** (Positive)

ID	Before	After	**Change P**	Max
1	1	2	1	4
2	2	3	1	3
3*	3	2	-1	2
4	2	2	0	3
5	3	4	1	2
6	3	4	1	2
7	2	5	3	3
Sum (% Max)			**6 (32%)**	19

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