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Randomized Crossover Study of the Natural Restorative Environment Intervention to Improve Attention and Mood in Heart Failure

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Background: In heart failure (HF), attention may be decreased because of lowered cerebral blood flow and increased attentional demands needed for self-care. **Objective:** Guided by the Attention Restoration Theory, the objective was to test the efficacy of the natural restorative environment (NRE) intervention on improving attention and mood among HF patients and healthy adults. **Methods:** A randomized crossover pilot study was conducted among 20 HF patients and an age- and education-matched comparison group of 20 healthy adults to test the efficacy of the NRE intervention compared with an active control intervention. Neuropsychological tests were administered to examine attention, particularly attention span, sustained attention, directed attention, and attention switching, at before and after the intervention. Mood was measured with the Positive and Negative Affect Schedule. **Results:** No significant differences were found in attention and mood after the NRE intervention compared with the control intervention among the HF patients and the healthy adults. In analyses with HF patients and healthy adults combined (n = 40), significant differences were found. Compared with the control intervention, sustained attention improved after the NRE intervention ($P = .001$) regardless of the presence of HF. Compared with the healthy adults, HF patients performed significantly worse on attention switching after the control intervention ($P = .045$). **Conclusions:** The NRE intervention may be efficacious in improving sustained attention in HF patients. Future studies are needed to enhance the NRE intervention to be more efficacious and tailored for HF patients and test the efficacy in a larger sample of HF patients.

KEY WORDS: heart failure, intervention studies, neuropsychological tests, psychophysiology; attention

Heart failure (HF) is a prevalent public health concern, affecting 5.7 million adults in the United States.[1] Although survival after an HF diagnosis has improved, death and hospital readmission rates remain high. Over 80% of HF patients are hospitalized at least once, 43% are hospitalized more than 4 times, and the mortality rate is 50% at 5 years after diagnosis.[1] These serious consequences suggest that there are barriers to HF care, including cognitive impairments with decreased attention.[2–5]

Cognitive impairments have been reported in 25% to 50% of HF patients, and impairments are often found in attention, memory, and executive function.[2] Cognitive deficits have important implications in terms of self-care.[3,4] The HF self-care regimen, which includes restricting dietary sodium intake and monitoring symptoms of dyspnea and fatigue, is so complex that the process of learning and applying self-care requires substantial cognitive effort every day.[5,6] Adherence to self-care regimens is low in almost a third of HF patients in the United States, and the estimated adherence rate varies from 2% to 90% based on the particular type of self-care and the measurements used.[4,7] Cognitively impaired patients may be at particular risk for not being able to adhere to self-care[5,8–11] and thus are at risk for higher mortality.[12]

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Attention is defined as "the regulating of various brain networks by attentional networks involved in maintaining the alert state, orienting, or regulation of conflict,"[13(p2)] and it serves as a basic set of mechanisms involved in perceiving the world and regulating our thoughts and feelings.[13–15] Thus, attention is essential for performance of daily activities such as self-care.[13,16] The neural basis of attention is the prefrontal cortex,[13] and this area has been reported as impaired among patients with HF.[17,18] Three important factors related to the pathophysiology of HF may be involved in the attention impairment found in HF patients: low blood and oxygen supply to the brain, HF symptoms distracting and interfering with patients' daily activities, and complex HF treatment. Because of the symptomatology of HF and the complexity of the HF treatment regimen, increased demands for attention are placed on the very patients who may already have decreased attention.[10,19] These increased attentional demands may deplete neural networks and lead to attentional fatigue manifested as decreased attention to concentrate on tasks.[16,20]

Attention is one of the most commonly impaired cognitive domains in HF,[2] occurring in 15% to 27.4% of HF patients.[21] Compared with healthy persons and cardiac patients without HF, HF patients have significantly worse attention.[22,23] Clinical characteristics of HF related to decreased attention are lowered left ventricular ejection fraction and increased HF severity.[21,24,25] These findings were consistent with the results of a literature review of previous studies showing cognitive impairment to be a factor in HF.[20] Importantly, impaired attention has been associated with poorer medication management and inconsistent self-care behaviors.[9,26]

Despite the fact that decreased attention has been documented in HF, there is a lack of knowledge about the specific aspects of attention that are decreased. Attention is a complex concept with several subdomains, including directed attention, sustained attention, attention switching, and attention span.[27] However, no studies have investigated attention in sufficient depth to determine the extent to which the different aspects or subdomains of attention are diminished in HF. Furthermore, the HF literature on decreased attention has focused on physiological changes in the heart and the brain and has not included increased attentional demands as a variable that would influence attention. Moreover, no interventions specifically directed at improving attention in HF were found, although some interventions have been reported, which were designed to improve memory and cognitive function, such as cognitive training.[28,29] Besides cognitive training, there is an attention intervention, the natural restorative environment intervention (NRE), which has shown efficacy in improving attention.

The theoretical foundation of the NRE can be found in the Attention Restoration Theory, in which increased exposure to nature is proposed to significantly decrease unnecessary use of attention and thereby refresh attentional resources and improve attention.[14] In the theory, attention is conceptualized into 2 components: directed and involuntary attention. Directed attention is conceptually defined as a cognitive-control process that requires a great deal of mental effort to focus on something that is not particularly interesting by ignoring competing stimuli.[14,27,30] Directed attention, unlike other cognitive domains, is fragile and easily becomes fatigued.[14] In contrast to directed attention, involuntary attention is conceptually defined as attention that is captured by intriguing or novel stimuli, such as moving objects and wild animals.[14,27] Involuntary attention requires little or no mental effort to focus on stimuli and is never fatigued. The requirement of little or no mental effort is important because it serves as the basis for using involuntary attention as an intervention to restore attention by resting the neural network for directed attention.[14,31]

Attention Restoration Theory posits that nature might be the best source for improving attention because it contains 4 elements of attention restorative stimuli (Table 1).[14,32] Because of these elements, attentional fatigue can be reduced and attention can be restored while interacting with nature.[14] Based on Attention Restoration Theory, various formats of interventions using the natural environment have been tested and found to be efficacious in improving attention in diverse populations,[31] for example, a 20-minute walk in the park among 17 children with attention deficit hyperactivity disorder,[33] doing nature activities (eg, gardening, walking) for 120 minutes per week among 157 women with early breast cancer,[34] and viewing nature pictures on a computer screen among 12 university students.[35]

In addition to improved attention, improved mood was found in 2 NRE intervention studies. In a randomized crossover study of 28 university students, students had increased positive mood after a 50-minute walk in an arboretum compared with a 50-minute walk in the downtown area.[35] The same intervention was conducted with 20 patients with major depression, and the patients' mood also improved with the NRE intervention.[36] The studies found that improved attention was not driven by mood. Instead, improved attention, which results from reducing attentional fatigue by the NRE interventions, may improve mood because negative moods such as irritability and anxiety can be symptoms of attentional fatigue.[14] Therefore, the positive effects on mood from interactions with nature would be consequences of the interventions.

Mood has shown some impact on health behaviors that may be due to disrupted attention focus or

TABLE 1 Elements of Attention Restorative Stimuli: Nature Versus Urban Environment[14]

Elements	Nature	Urban
Feeling of being away	Often	Less often
Sense of fascination	Soft	Hard
Extended feelings	More	Less
Compatibility between person and environment, which permits a person can function based on his/her purposes	High	Low
		

Source: http://enl.uchicago.edu/stimuli-software/. In the public domain.

arousal.[37] In HF, depressed mood and anxiety have mostly been investigated in terms of their relationships with health outcomes such as functional status, mortality, and quality of life.[38] Depression is prevalent in HF patients (>20%) and the prevalence increases with advanced HF symptoms such as fatigue, dyspnea, and physical inactivity.[34,39] The presence of depression is more likely associated with more negative mood experiences in HF patients leading to negative health outcomes such as higher mortality.[38–40] Not only negative moods but also the impact of positive mood has been investigated in relation to inflammatory biomarkers and compliance with self-care.[41,42] Although mood is more temporary and amenable compared with depression, the relationships between mood and attention and/or attentional fatigue have not been investigated in HF.

In summary, decreased attention and negative moods are common in HF patients. Interventions directly aimed at improving attention in HF patients have not been reported. The NRE intervention— viewing nature pictures on a computer screen—used in this study was already found to be safe and efficacious in improving attention among healthy young adults. The intervention is feasible with minimal physical effort and can be widely disseminated at low cost. Improved attention may have a positive impact on HF self-care activities, such as medication management, for example. However, the efficacy of the NRE intervention in improving attention and mood has not been tested among HF patients.

The primary aim of this randomized crossover pilot study was to examine the efficacy of the theory-based NRE intervention compared with the active control intervention on attention in HF patients and healthy age- and education-matched adults. The secondary aim was to examine the efficacy of the NRE intervention on mood. Two research questions were addressed for further evaluation of the intervention efficacy by the presence of HF and preference regarding the content of each intervention.

Methods

Design and Procedures

A randomized crossover design (within-subject, 2 treatments, 4 observations) was used to test intervention efficacy because this design has 2 advantages over a randomized controlled trial for this study. First, the crossover design is efficient in the early stage of intervention testing because it controls between-subject variability. Second, the crossover design can be used when the effects of the intervention are expected to be observed quickly after the intervention with short washout.[43,44] The study was approved by the university institutional review board. All participants provided written informed consent. Data collection was conducted at participants' homes or a mutually agreed upon location. Participants were randomized to the intervention orders with a 1:1 ratio based on a computer-generated random list, and the allocation sequences for intervention order were enclosed in envelopes with study identification numbers. After informed consent was obtained, participants completed baseline surveys and neuropsychological tests. Next, the envelope with the allocation sequence was opened, the assigned intervention was delivered, and neuropsychological tests were administered. After 1 week of washout period, the second interview was made to deliver the assigned intervention, which was different from the previous one that had been delivered already. A total of 2 visits and 4 observations per participant were made. Each intervention took approximately 7 minutes to complete and neuropsychological tests at each time point took 20 to 30 minutes to complete. Data collectors were blinded to random group sequence and only the interventionist knew the sequence. Data were collected from April 2014 to May 2015.

Sample

Patients with HF (n = 27) were recruited from a cardiology outpatient clinic and age- and education-matched healthy adults (n = 21) were recruited from a Web-based recruitment registry for research at a university. Twenty HF patients and 20 healthy adults completed the study. The sample size of 20 HF patients and 20 healthy adults was calculated from data obtained from a previous study in which the same intervention was tested among university students.[35] The effect size for attention restoration in the previous study was medium (0.65) from Digit Span Backward and large (−1.82) from the Attentional Network Test among healthy young adults.[35,45] For this study in HF patients, more expected variance (σ = 1.1) with the same effect size from Digit Span Backward (0.65) was used to find the adequate sample size. The sample size of 20 for each group was calculated for 2 repeated measures per subject corresponding to data collected under the 2 forms of treatment (ie, intervention and control condition) in 2 groups (ie, HF patients and healthy adults).

Patients with HF were recruited first and healthy adults recruited second to match age and education to the HF patients. The sample of age and education-matched healthy adults was included to assess the possible effects of HF presence on intervention responses (a research question described above). The healthy control group enabled careful examination of the intervention effect after adjusting for age and education.

Inclusion criteria for HF participants were (1) adults older than 21 years, (2) diagnosed with HF, and (3) able to read and hear the English language. Inclusion criteria for healthy adults were the same except for the diagnosis of HF. Exclusion criteria for both groups were (1) having major neurological or psychiatric disorders (eg, dementia, stroke, or attention deficit hyperactivity disorder); (2) uncorrected visual impairment; (3) color blindness; and (4) Mini-Mental Status Examination score lower than 24 because of possible dementia (cutoff point 22 for participants with less than ninth grade education).[46,47]

Interventions

The interventions[35] had been originally developed and tested by a coauthor (M.G.B.) in healthy young adults before the interventions were adopted and extended to HF patients in this study. The NRE intervention consisted of participants viewing 50 photographs of nature scenery (eg, sea, woods, mountains, rocks, and flowers).[35] Each photograph was displayed once for 7 seconds on a laptop computer screen.

The active control intervention consisted of participants viewing 50 photographs of urban views (eg, buildings, streets with cars and pedestrians, and parking spaces without any nature scenery). This control intervention had the same delivery features as the NRE intervention in terms of time (7 seconds for each photograph), dose (50 photographs), and mode (computer based). The core elements of the interventions and sample photographs of each intervention are shown in Table 1.

Measures

Attention

Four neuropsychological tests, the Multi-Source Interference Task (MSIT), Digit Span Test, Trail Making Test, and Stroop test, were administered at pre and post interventions. These 4 validated neuropsychological tests, which measure directed attention, sustained attention, attention switching, and attention span (Figure 1), were selected because attention involves different skills in different contexts and a single measure of attention as an outcome variable could result in a limited assessment of attention.[48,49]

The MSIT indirectly examines the function of the cingulo-fronto-parietal cognitive/attention network,[50,51] which supports directed attention. In this test, on the computer screen, 3 numbers and/or letters were displayed (combinations of 1, 2, 3, and X), and participants were instructed to identify the number that was different from the other 2 numbers or letters within 2 seconds. There are 2 types of trials, congruent and incongruent. Congruent trials have a target number that is always matched in position (eg, 1XX, X2X, or XX3) with 2 X letters. In contrast, incongruent trials have only numbers and the target number is never matched with its position (eg, 212, 233, or 332).[50] Lower error rates and shorter response time represent better attention and these scores were used in the analyses. Content validity of MSIT examining cingulo-fronto-parietal cognitive/attention network has been supported with functional magnetic resonance imaging in healthy individuals.[50,51]

The Digit Span Test is a widely used standardized measure of attention span that is free from distractability.[52] Digit Span Forward demands low attention span, whereas Digit Span Backward requires high attention span.[52] Participants were instructed to repeat the sequence of numbers that the tester said aloud immediately after the tester finished saying the numbers. The numbers of digits participants repeated

Sub-domain	Definition	Measures
Directed attention	Cognitive-control process that requires a great deal of mental effort to focus on something that is not particularly interesting by ignoring competing stimuli	Composite scores of MSIT average interference z scores, Trail Making (B - A) z scores, and Stroop Test average interference z scores
Sustained attention	The ability to monitor targeted stimuli for a prolonged time and maintain focus	Composite scores of MSIT congruent trails, Trail Making Test A, and Stroop Test congruent trials z scores
Attention switching	The ability to switch the focus of attention between multiple tasks or stimuli rapidly	Composite scores of Stroop error rates and response time difference between switched and non-switched trials
Attention span	The amount of time an individual can sustain attention to one task or the amount of material that can be processed during exposure to stimuli	Digit Span Test (Forward and Backward)

FIGURE 1. *Map of attention subdomains and measures.*

correctly were used for analysis, with higher scores indicating better attention. In past studies, test-retest reliability coefficients ranged between .66 and .89.[52] Construct validity was supported by comparing healthy and closed head injury patients.[53]

The Trail Making Test is a standardized measure requiring effective inhibition of competing stimuli to complete the tasks rapidly and accurately.[54,55] Part A requires participants to connect circles numbered 1 to 25 in order as quickly as possible. Part B requires participants to connect a series of 25 circles numbered 1 to 13 randomly intermixed with letters from A to L, alternating between numbers and letters in ascending order. A shorter completion time represents better attention. The reliability of alternate forms of the Trail Making Test was .78 among 15 head injury patients[56] and .89 and .92 among over 300 healthy adults.[57] Construct validity was supported among healthy adults and patients with closed head injury.[53] The Trail Making Test was validated by a functional magnetic resonance imaging study of 12 healthy young adults and correlated with frontal lobe activation.[58]

The Stroop test is involved in selective processing of different visual features on the test (letters and ink colors of words in color).[52,53,59] A computerized Stroop test was programmed with trial displays of 4 colors (red, blue, yellow, and green) and 2 commands (reading letters of color names or print colors). Congruent trials showed color names that had the same letters and print colors, and incongruent trials showed color names that had different letters and print colors. Three trials were provided at each observation, reading letters, reading colors, and a combination of reading letters and colors. In the combination trials, the trials that had switched command (word to color, or color to word) were called switched trials, and trials that had the same command (color to color, or word to word) were called nonswitched trials.[50] In past studies, the reliability of Stroop test was satisfactory.[60] Construct validity was supported in patients with traumatic brain injury,[61] and a meta-analysis showed that impaired performance on the Stroop test was most common in patients with frontal lobe lesions.[62]

Mood

The Positive and Negative Affect Schedule (PANAS) scale was used.[63] It is a 20-item scale composed of two 10-item mood scales of positive mood and negative mood. Participants were asked to rate the extent to which they felt the mood described by the adjectives at that very moment on 5-point Likert scales. Possible scores range from 10 to 50 for both scales. In 80 chronic HF patients, internal consistency was Cronbach's α of .86 for the positive scale and .85 for the negative scale.[64] In the current sample, Cronbach's α was .82 for the positive scale and .67 for the negative scale in the HF patients and .91 for the positive scale and .55 for the negative scale in the healthy adults. Convergent and discriminant validity have been supported in nonclinical populations.[63]

Participant Characteristics

Participants' demographic, biological, clinical, and cognitive characteristics were obtained at the beginning of the interview and from the medical record to describe the sample. Demographic characteristics included age, gender, race, ethnicity, years of education, marital status, and employment status.

Biological characteristics obtained were blood pressure, pulse rate, and oxygen saturation (SpO_2). Blood pressure was measured twice following guidelines from the American Heart Association at the beginning of each visit.[65] SpO_2 was measured by the Nonin WristOx 3100, which monitors proximal saturated oxygen and pulse rate from a fingertip probe every 4 seconds.

Clinical characteristics of left ventricular ejection fraction, New York Heart Association class, and brain natriuretic peptide levels were collected from medical chart review to describe HF function and severity for HF patients. The HF symptom severity was assessed using a visual analog scale for common HF symptoms that may decrease attention, the Patient Reported Outcomes Measurement Information System Fatigue Short Form, and Current Dyspnea Status. The Patient Reported Outcomes Measurement Information System fatigue short form has 8 items and responses are rated on 5-point Likert scales. Reliability and validity were supported in 48 HF patients.[66] Current dyspnea status has 1 question, "How much difficulty are you having in breathing now?" Participants were asked to answer on a 5-point Likert scale. Content and predictive validities were supported among 58 HF patients.[67] The visual analog scale was administered to healthy adults to compare symptoms and validate differences between the 2 groups.

Cognitive characteristics were measured at baseline to describe participants' level of attentional demands of chronic illness, cognitive activities performed in daily living, nature activities performed in daily living, and perceived effectiveness in performing cognitive activities. First, to measure the attentional demands of chronic illness, an 11-item questionnaire with 6-point response scales was administered on which participants reported the amount of mental effort they needed to perform self-care activities (eg, diet, medications, and symptom monitoring). Possible scores range from 0 to 55, and higher scores represent greater attentional demands. In the current HF sample, internal consistency of the scale was Cronbach's α = .91. Second, cognitive activities performed in daily living were assessed by the Florida Cognitive Activities Scale on which participants report the frequency, intensity, and duration of performing 25 cognitive activities.[68] Possible scores range from 0 to 100, and higher scores indicate more frequent cognitive activities with or without more challenging activities (eg, new and complex activities). Cronbach's α values were .76 to .77 in HF patients.[28] In the current HF sample (n = 20), the internal consistency reliability was .68. Third, number and type of nature activities performed in the previous month (eg, walking in the park, listening to birds, and tending plants) were measured using an 8-item survey questionnaire asking activity frequency, time, and restorative experiences.[34] Fourth, perceived effectiveness in performing common cognitive activities that require directed attention was examined by the Attentional Function Index,[69,70] which consists of 13 items on 0 to 10 response scales.[71] Possible scores range from 0 to 130 and higher scores indicate better attention. Internal consistency reliability was satisfactory in a past study among 72 undergraduate students (Cronbach's α = .84)[16] and in another among 172 women (Cronbach's α = .92).[70] In the current sample, Cronbach's α was .82 among 20 HF patients and .90 among 20 healthy adults.

Preferences in Interventions

To validate the interventions and monitor intervention fidelity, participants were asked the question "Do you like the picture?" using 1 ("like"), 2 ("neutral"), or 3 ("do not like") for each photograph. Total scores ranged from 50 to 150 for each set of interventions. The total scores were transformed from 0 to 100 and reversed, so that higher scores indicated more positive preferences and a score of 50 indicated neutral feelings about the intervention.

Statistical Analysis

Descriptive and univariate analyses were computed to describe sample characteristics. Pearson correlations were conducted to examine relationships between sample characteristics and outcome variables before hypothesis testing. All neuropsychological tests were treated equally in the analysis, and 4 individual and 3 composite scores of the attention tests were analyzed. Composite scores were calculated to examine directed attention, sustained attention, and attention switching. For all composite z scores, scores above 0 mean better performance than average. Detailed information on composite score calculation is described in Figure 1.

To test the efficacy of the NRE intervention in improving attention and mood, linear mixed models were computed.[72] Separate mixed models were created for attention and mood in the HF and healthy adult groups. Age, education, and order of intervention were entered into the models as covariates. Interactions between types of treatment (NRE and active control) and time (pretest or posttest) were entered into the models. Pairwise comparisons were used for post hoc analyses. To examine research questions on the influences of preferences and HF diagnosis, data from both groups were added together and the group and preference variables were added to the linear mixed models in a combined sample of both HF and healthy adults.

As post hoc analysis, effect sizes (f^2) for the treatment by time interaction in this sample were estimated based on the variances explained in mixed models, and confidence intervals for the effect sizes were estimated from a bootstrap approach.[73,74] The effect sizes were defined as small, f^2 = 0.02; medium, f^2 = 0.15; and large, f^2 = 0.35.[45] Observed power was estimated by a bootstrap approach.[74] Analyses for the proposed aims were performed using SPSS Statistics 21.0, and post hoc analysis was completed using STATA 14. A significance level P <.05 was used.

Results

Twenty HF and 20 age- and education-matched healthy adults completed the study (Figure 2). Seven HF patients and 1 healthy adult withdrew because of being too busy (n = 3), too sick (n = 2), or for unknown reasons (n = 3). No one was ineligible due to Mini-Mental State Exam scores below 24. Participant characteristics at baseline are presented in Table 2.

Compared to healthy adults, HF patients performed worse on the attention measures of MSIT, Trail Making test, and Stroop test, but not Digit Span test (Table 3) at baseline. In terms of sub-domains of attention, HF patients also had poorer composite scores for directed attention (P = .016) and sustained attention (P = .003) but not attention switching (P = .444) or attention span (P = .910 and .063 for Digit Span Forward and Backward, respectively) compared to healthy adults. Mood did not differ between HF and healthy adults, and both had high levels of positive mood and low levels of negative mood.

In the linear mixed models analysis, HF patients did not show significant time-by-treatment interaction effects for the NRE intervention compared with the control intervention in any of the attention tests and subdomains of attention (Table 4). Healthy adults did not show significant time-by-treatment interaction effects as well (Table 5). There were no significant changes in positive and negative mood status after NRE intervention compared with the control

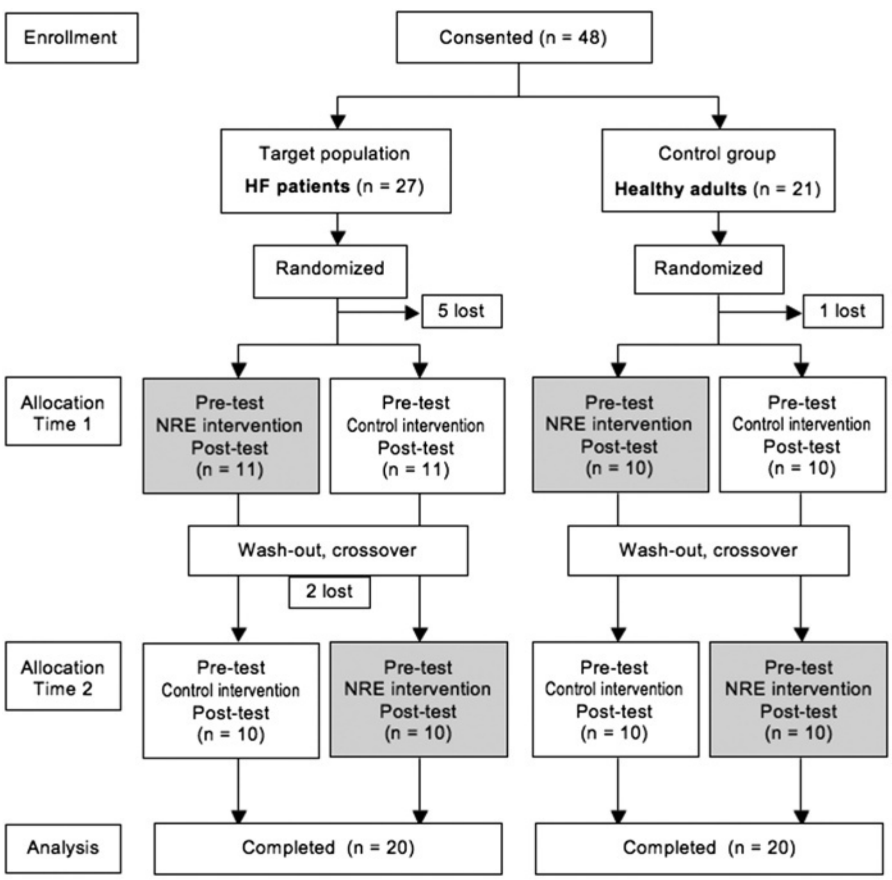

FIGURE 2. *CONSORT flow diagram of the study.*

TABLE 2 Characteristics of Heart Failure and Healthy Participants at Baseline

Characteristic	Total (n = 40)	HF Patients (n = 20)	Healthy Adults (n = 20)	*t* or X^2 (*P*)
Age, mean ± SD, y	59.2 ± 12.1	59.5 ± 12.8	58.8 ± 11.6	0.18 (.857)[a]
Education, mean ± SD, y	15.0 ± 2.2	14.8 ± 2.4	15.3 ± 2.0	−0.71 (.483)[a]
Mini-Mental Status Examination, mean ± SD	28.1 ± 1.7	27.4 ± 1.8	28.8 ± 1.2	32.13 (.007)[a,b]
Gender, n (%)				0.10 (1.000)
Men	21 (52.5)	11 (55)	10 (50)	
Women	19 (47.5)	9 (45)	10 (50)	
Race, n (%)				2.59 (.274)
African American	3 (7.5)	2 (10)	1 (5)	
Asian	2 (5)	2 (10)	0 (0)	
White	35 (87.5)	16 (80)	19 (95)	
Ethnicity, n (%)				0.36 (.834)
Hispanic	2 (5)	1 (5)	1 (5)	
Non-Hispanic	35 (87.5)	17 (85)	18 (90)	
Unknown	3 (7.5)	2 (10)	1 (5)	
Marital status, n (%)				0.11 (1.000)
Married	25 (62.5)	12 (60)	13 (65)	
Not married	15 (37.5)	8 (40)	7 (35)	
Employment, n (%)				3.01 (.222)
Employed	13 (32.5)	4 (20)	9 (45)	
Not employed	4 (10)	2 (10)	2 (10)	
Retired	23 (57.5)	14 (70)	6 (45)	
Handedness, n (%)				1.56 (.407)
Right	33 (82.5)	15 (75)	18 (90)	
Left	7 (17.5)	5 (25)	2 (10)	
Florida Cognitive Activities Scale, total, mean ± SD	47.3 ± 9.8	45.4 ± 10.9	49.2 ± 8.4	−1.25 (.219)[a]
Attentional Function Index, total, mean ± SD	98.1 ± 20.1	86.5 ± 19.2	109.8 ± 13.3	−4.47 (<.001)[a,b]
Effective action	53.1 ± 11.9	40.3 ± 11.0	60.9 ± 6.4	−5.45 (<.001)[a,b]
Attentional lapses	22.9 ± 5.5	20.8 ± 6.6	25.0 ± 3.3	−2.95 (.015)[a,b]
Interpersonal effectiveness	22.2 ± 6.5	20.4 ± 6.9	23.9 ± 5.7	−1.77 (.086) [a]
Activity in nature, frequency, mean ± SD	9.2 ± 6.3	10.0 ± 5.9	7.5 ± 5.7	1.36 (.181) [a]
Systolic blood pressure, mean ± SD, mm Hg	117.6 ± 14.3	110.9 ± 8.7	124.4 ± 15.7	−3.37 (.002)[a,b]
Diastolic blood pressure, mean ± SD, mm Hg	70.0 ± 11.6	66.2 ± 9.1	73.8 ± 12.7	−2.19 (.035)[a,b]
SpO_2[c], mean ± SD[d], %	97.1 ± 1.3	96.6 ± 1.4	97.6 ± 1.0	−2.67 (.011)[a,b]
Time having SpO_2 <95%, mean ± SD[d], min	5.5 ± 12.8	8.8 ± 17.1	2.1 ± 4.5	1.70 (.103)[a]
Pulse rate, mean ± SD[d]	73.3 ± 10.9	75.1 ± 13.0	71.6 ± 8.2	1.02 (.313)[a]
HF symptoms (0–10, higher is worse), mean ± SD				
Breathlessness at rest	0.6 ± 1.4	1.2 ± 1.8	0 ± 0	2.88 (.010)[a,b]
Breathlessness with activity	3.1 ± 2.9	4.5 ± 2.6	1.7 ± 2.6	3.36 (.002)[a,b]
Fatigue	2.0 ± 2.6	3.4 ± 2.8	0.5 ± 1.1	4.31 (<.001)[a,b]
Daytime sleepiness	2.5 ± 3.9	4.3 ± 3.1	0.7 ± 1.0	5.05 (<.001)[a,b]
Overall symptom impact on everyday life	2.6 ± 3.4	4.7 ± 0.4	3.6 ± 1.0	5.09 (<.001)[a,b]
Left ventricular ejection fraction, mean ± SD	–	37.6 ± 15.1	–	–
Brain natriuretic peptide before enrollment, mean ± SD	–	295.7 ± 336.3	–	–
New York Heart Association class, n (%)	–			
II		9 (45)		
Between II and III		4 (20)		
III		6 (30)		
IV		1 (5)	–	–
PROMIS fatigue SF 8a, mean ± SD	–	22.2 ± 8.9	–	–
Current dyspnea status, mean ± SD	–	1.4 ± 0.8	–	–

Abbreviations: HF, heart failure; PROMIS, Patient Reported Outcomes Measurement Information System.
[a]*P* value from *t* tests, all others are *P* value from X^2 tests.
[b]$P < .05$.
[c]Peripheral capillary oxygen saturation from pulse oximeter.
[d]Sample size for healthy group = 19.

intervention in the HF or healthy adults groups (Tables 4 and 5).

Linear mixed models in the combined sample of HF and healthy participants showed that preferences for attention improvement differed significantly after the NRE intervention. Specifically, sustained attention significantly improved after the NRE intervention, and the higher the preferences scores, the better the sustained attention (post hoc analysis, $F = 9.679$, $P = .002$).

TABLE 3 Comparisons of Attention and Mood Between Heart Failure and Healthy Participants at Baseline (n = 40)

	HF Patients (n = 20)	Healthy Adults (n = 20)	*t*	*P*
Attention				
MSIT				
Error rate, %				
Congruent	0.7 ± 1.3	0.1 ± 0.2	2.13	.045[a]
Incongruent	5.7 ± 3.3	4.4 ± 3.7	1.18	.244
Response time, ms				
Congruent	776 ± 135	701 ± 116	1.87	.070
Incongruent	1081 ± 137	977 ± 153	2.25	.029[a]
Digit Span Test (score)				
Forward	6.75 ± 1.33	6.70 ± 1.46	0.11	.910
Backward	4.25 ± 1.25	4.96 ± 1.05	−1.92	.063
Trail Making Test, s				
A (only numbers)	41.06 ± 13.87	26.68 ± 9.84	3.78	.001[a]
B (number-letter)	100.40 ± 49.45	59.74 ± 20.04	3.41	.002[a]
Stroop test[b]				
Error rate, %				
Congruent	2.6 ± 3.5	1.3 ± 3.4	1.19	.241
Incongruent	26.0 ± 16.8	13.0 ± 10.7	2.88	.007[a]
Nonswitched	9.6 ± 15.0	8.7 ± 13.0	0.19	.851
Switched	10.9 ± 15.0	8.0 ± 10.6	0.69	.492
Response time, ms				
Congruent	421 ± 94	295 ± 68	0.51	.611
Incongruent	1646 ± 517	1703 ± 521	−0.35	.730
Nonswitched	1452 ± 623	1757 ± 737	−1.40	.170
Switched	1596 ± 660	1745 ± 579	−0.75	.458
Composite *z* scores of attention[b]				
Directed attention	0.64 ± 1.83	−0.73 ± 1.51	2.54	.016[a]
Sustained attention	0.95 ± 2.27	−0.95 ± 1.40	3.18	.003[a]
Attention switching	0.07 ± 0.55	−0.07 ± 0.60	0.77	.444
Mood, PANAS (score)				
Positive mood	33.10 ± 7.72	32.20 ± 8.81	0.34	.733
Negative mood	11.70 ± 2.92	11.00 ± 1.59	0.941	.353

For attention measures, higher scores indicate worse attention, except for the Digit Span Test.
Abbreviations: MSIT, Multi-Source Interference Task; PANAS, Positive and Negative Affect Schedule.
[a]$P < .05$.
[b]Sample size for healthy adults = 19.

The presence of HF was predictive of different intervention responses. Specifically, the effect of the control intervention was significantly different on attention switching between HF and healthy adults (time × treatment × group interaction, $P = .045$). The HF patients had significantly decreased attention switching performance after the control intervention, whereas the healthy adults preserved their attention switching performance after the control intervention.

The average preference score for the photographs was significantly higher for the NRE intervention (80.60 ± 16.93) compared with the control intervention (45.28 ± 17.02) ($P = < .001$), which indicates more positive preference for the NRE intervention. The preference for each type of intervention did not differ between HF and healthy adults ($P = .933$). More favorable preferences scores were predictive of more positive mood ($P = < .001$), but there was no time-by-treatment by preferences interaction effect.

The effect sizes of the NRE intervention compared with the control intervention were very small to small, and the observed power was low (range, 2.4% to 15.4%) among HF patients. Among healthy adults, the effect sizes were very small to moderately small, and the observed power relatively higher (range, 1.3% to 65.3%) than HF patients.

Discussion

This pilot study is important because to our knowledge, it is the first experimental study to test the efficacy of the theory-based NRE intervention to improve attention and mood among a carefully characterized sample of HF patients. The focus on attention, measurement of attention subdomains using 4 valid tests, and inclusion of an age- and education-matched healthy adult comparison group are additional strengths of the study. The study provides preliminary support for the NRE improving sustained attention in the combined sample.

Comparison of demographic, clinical, and study variables supported differences between the HF patients and healthy adults. Although there were no differences

TABLE 4 Means, Standard Deviations, and Linear Mixed Models Analysis for Outcome Variables in Heart Failure (n = 20)

	NRE Intervention (n = 20)		Control Intervention (n = 20)		Mixed-Models Analysis, *P*					
Outcome Variables	**Pretest**	**Posttest**	**Pretest**	**Posttest**	**Age**	**Education**	**Order**	**Time**	**Treatment**	**Treatment × Time**
Attention										
MSIT										
Error rate, %										
Congruent	0.56 ± 1.18	1.24 ± 4.42	0.48 ± 0.88	1.08 ± 1.96	.229	.048[a]	.719	.056	.717	.901
Incongruent	4.79 ± 3.40	4.59 ± 4.42	4.67 ± 2.42	4.27 ± 3.92	.564	.081	.801	.646	.729	.874
Response time, ms										
Congruent	755 ± 143	737 ± 123	741 ± 116	721 ± 114	.065	.232	.318	.090	.156	.932
Incongruent	1047 ± 150	1019 ± 145	1043 ± 123	1015 ± 128	.074	.117	.380	.042[a]	.792	.985
Digit Span Test (score)										
Forward	6.80 ± 1.44	6.55 ± 1.19	6.70 ± 1.22	6.55 ± 1.15	.452	.264	.368	.279	.785	.785
Backward	4.40 ± 1.54	4.55 ± 1.79	4.30 ± 1.75	4.85 ± 1.42	.720	.130	.341	.115	.649	.364
Trail Making Test, s										
A (only numbers)	41.90 ± 14.87	41.80 ± 21.67	41.92 ± 17.99	44.38 ± 28.18	.020[a]	.141	.953	.703	.674	.679
B (number-letter)	97.78 ± 47.52	87.37 ± 45.35	98.29 ± 52.80	88.04 ± 44.39	.009[a]	.051	.897	.019[a]	.891	.985
Stroop test[b]										
Error rate, %										
Congruent	4.17 ± 8.14	2.5 ± 3.24	3.47 ± 4.84	2.92 ± 3.55	.861	.441	.371	.332	.903	.626
Incongruent	23.61 ± 18.28	18.19 ± 18.30	19.72 ± 15.81	14.31 ± 16.03	.494	.248	.412	.035[a]	.126	1.000
Nonswitched	10.49 ± 15.69	10.24 ± 14.28	11.12 ± 17.21	8.66 ± 12.78	.685	.114	.255	.582	.846	.653
Switched	12.75 ± 14.99	7.16 ± 8.71	9.63 ± 13.80	6.55 ± 8.19	.993	.188	.376	.067	.425	.590
Response time, ms										
Congruent	1432 ± 476	1352 ± 338	1285 ± 304	1281 ± 296	.367	.978	.534	.429	.043[a]	.476
Incongruent	1641 ± 541	1616 ± 513	1598 ± 353	1659 ± 387	.103	.701	.869	.797	.999	.554
Nonswitched	1485 ± 405	1370 ± 416	1509 ± 519	1492 ± 447	.134	.475	.874	.359	.310	.492
Switched	1619 ± 693	1654 ± 547	1373 ± 376	1475 ± 464	.248	.513	.709	.520	.047[a]	.750
Composite *z* scores of attention[b]										
Directed attention	0.08 ± 1.96	−0.45 ± 2.25	0.25 ± 1.74	−0.37 ± 1.68	.079	.079	.823	.024[a]	.619	.849
Sustained attention	1.17 ± 2.60	1.09 ± 3.34	0.77 ± 2.27	1.10 ± 1.68	.039[a]	.064	.704	.713	.571	.575
Attention switching	0.11 ± 0.45	0.06 ± 0.60	−0.25 ± 0.68	−0.18 ± 0.50	.716	.248	.587	.938	.016[a]	.636
Mood, PANAS (score)										
Positive mood	30.1 ± 7.9	30.6 ± 10.5	31.9 ± 7.3	30.5 ± 8.2	.866	.306	.021[a]	.727	.521	.497
Negative mood	11.9 ± 4.1	11.7 ± 4.3	11.6 ± 3.2	10.5 ± 1.8	.409	.689	.105	.322	.254	.492

Abbreviations: MSIT, Multisource Interference Task; NRE, natural restorative environment; PANAS, Positive and Negative Affect Schedule.

[a] $P < .05$.

[b] Sample size for healthy group = 19.

TABLE 5 Means, Standard Deviations, and Linear Mixed Models Analysis for Outcome Variables in Healthy Adults (n = 20)

	NRE Intervention (n = 20)		Control Intervention (n = 20)		Mixed-Models Analysis, *P*					
Outcome Variables	Pretest	Posttest	Pretest	Posttest	Age	Education	Order	Time	Treatment	Treatment × Time
Attention										
MSIT										
Error rate, %										
Congruent	0.36 ± 1.60	0.00 ± 0.00	0.05 ± 0.24	0.05 ± 0.21	.613	.852	.285	.331	.491	.337
Incongruent	4.13 ± 4.00	1.77 ± 1.99	3.67 ± 3.93	2.13 ± 2.20	.756	.255	.983	<.001[a]	.922	.420
Response time, ms										
Congruent	661 ± 93	629 ± 79	662 ± 122	636 ± 127	.218	.408	.199	.026[a]	.729	.807
Incongruent	921 ± 148	890 ± 129	921 ± 152	886 ± 154	.553	.181	.701	.040[a]	.891	.895
Digit Span Test (score)										
Forward	6.85 ± 1.18	6.90 ± 1.41	6.80 ± 1.15	7.25 ± 1.21	.428	.273	.183	.218	.458	.324
Backward	5.05 ± 0.95	5.40 ± 1.57	4.55 ± 0.89	5.00 ± 1.45	.738	.343	.097	.096	.062	.833
Trail Making Test, s										
A (only numbers)	27.44 ± 9.67	24.68 ± 6.92	25.03 ± 7.28	24.95 ± 7.57	.052	.411	.806	.219	.352	.246
B (number-letter)	58.10 ± 22.37	53.03 ± 22.32	56.88 ± 20.66	55.25 ± 21.84	.006[a]	.560	.612	.225	.856	.533
Stroop test[b]										
Error rate, %										
Congruent	0.29 ± 0.88	1.17 ± 2.67	1.17 ± 3.38	0.44 ± 1.04	.956	.207	.067	.883	.883	.110
Incongruent	11.70 ± 9.82	4.24 ± 4.38	10.82 ± 10.47	5.70 ± 7.26	.266	.397	.665	<.001[a]	.831	.394
Nonswitched	8.89 ± 16.40	4.01 ± 5.93	6.76 ± 10.33	4.54 ± 7.42	.126	.727	.477	.091	.698	.520
Switched	6.04 ± 7.13	1.05 ± 3.15	5.88 ± 10.56	1.40 ± 4.35	.917	.568	.219	.001[a]	.945	.848
Response time, ms										
Congruent	1282 ± 300	1178 ± 275	1242 ± 332	1180 ± 352	.474	.798	.013[a]	.013[a]	.567	.531
Incongruent	1630 ± 510	1445 ± 467	1595 ± 522	1407 ± 423	.293	.930	.202	.001[a]	.480	.976
Nonswitched	1578 ± 479	1333 ± 540	1408 ± 441	1341 ± 484	.473	.743	.081	.016[a]	.201	.158
Switched	1547 ± 515	1311 ± 410	1515 ± 536	1283 ± 417	.313	.927	.114	.001[a]	.648	.977
Composite *z* scores of attention[b]										
Directed attention	−1.00 ± 1.66	−1.80 ± 1.31	−1.13 ± 1.44	−1.79 ± 1.11	.317	.428	.553	<.001[a]	.709	.673
Sustained attention	−1.09 ± 1.30	−1.64 ± 1.11	−1.37 ± 1.53	−1.72 ± 1.19	.088	.778	.043[a]	.005[a]	.228	.527
Attention switching	−0.25 ± 0.69	−0.17 ± 0.40	−0.01 ± 0.42	−0.21 ± 0.51	.189	.578	.384	.545	.314	.170
Mood										
PANAS (score)										
Positive mood	33.20 ± 8.29	32.80 ± 9.53	31.55 ± 9.34	30.00 ± 9.69	.248	.103	.115	.219	.006[a]	.466
Negative mood	11.40 ± 1.93	11.15 ± 1.73	10.95 ± 1.67	11.40 ± 2.35	.095	.114	.181	.781	.781	.332

Abbreviations: MSIT, Multisource Interference Task; NRE, natural restorative environment; PANAS, Positive and Negative Affect Schedule.

[a] $P < .05$.

[b] Sample size for healthy group = 19.

in demographic variables between the groups, compared with the healthy adults, the HF patients had significantly lower systolic and diastolic blood pressure probably because of medications, lower average SpO_2, and more HF symptoms of dyspnea and fatigue. These clinical variables might have negatively influenced attention in HF patients.[75] This finding needs further testing in future studies.

At baseline, compared with healthy adults, HF patients had poorer attention after controlling for age and education. The findings are consistent with previous studies examining attention as part of cognitive function in HF.[20,22,23] A unique finding of this study is that specific subdomains of attention were examined with a neuropsychological battery of attention measures. Results showed that HF patients had poorer directed attention, sustained attention, and attention switching compared with healthy adults, and theoretically, sustained attention and attention switching can be supported by directed attention to complete tasks successfully. Thus, the results support that HF patients need to improve their directed attention and the NRE intervention is an appropriate approach.

The NRE intervention was not efficacious in improving attention and mood in either HF patients or healthy adults. The estimated effect sizes in this study were small on average but had relatively larger magnitude among healthy adults with larger observed power than HF patients. These findings were not consistent with previous testing of the same intervention in healthy young adults who had significant improvement with medium to large effect sizes.[35] Possible reasons for the inconsistent results may be differences in research methods (ie, measures of attention, intervention dose) and sample characteristics. In the current study, the MSIT was administered as a primary measure of directed attention compared with the Attentional Network Test in the previous study.[35] These 2 tests are similar in terms of components of tasks (congruent and incongruent trials and performance measured with error rates and response time) but the MSIT has shorter time to complete and higher level of task difficulties. In the current study, the intervention dose was 7 minutes, and one time, compared with 20 minutes in children with attention deficit hyperactivity disorder children[33] and 20 to 30 minutes in breast cancer women[34] in previous studies. Although there is a previous study that used the same NRE intervention with the same dose in healthy young adults and the intervention was efficacious, the current study sample was composed of HF patients with documented differences in blood pressure, oxygen saturation, and symptomatology. With aging, when the brain structure and function change, more changes have been found in gray matter, which may indicate less capacity to improve attention.[76] In other studies, the diagnosis of HF was closely related to worsened brain integrity, including the cingulate and prefrontal cortices in HF patients compared with healthy adults, and these brain areas support attention.[17,18,77] A lower capacity for attention or limited attentional resources may be associated with decreased responsiveness to the intervention because of the worsened brain integrity.

Although mixed models in separate group of HF and healthy adults did not show significant attention improvement after the NRE intervention, mixed models analyses in the combined sample with group (HF and healthy) and preference factors, participants showed significant improvements in attention, which was examined by a composite score of sustained attention. These results partially support the Attention Restoration Theory because sustained attention is a part of directed attention by James' definition of attention: directed vs. involuntary attention.[27] Sustained attention improvement in this study may have important implications for HF self-care because it is the type of attention that is required to adhere to complex medication and dietary regimens and monitor HF symptoms. Directed attention measured by interference skills is required for situations with distractions, and improvement in directed attention was expected after the NRE intervention based on Attention Restoration Theory. Descriptive statistics showed improved directed attention measured with interference skills, but this improvement did not reach significance level. A larger sample and stronger dose of the intervention might have provided more variances in observations and led to more positive results on attention improvement.

Compared with age- and education-matched healthy adults, HF patients not only had poorer attention at baseline but also responded to the interventions differently despite the fact that the HF patients were receiving optimal HF care. Specifically, HF patients showed a significant decrease in attention switching after the control intervention, whereas healthy adults maintained their performance of attention switching. Possible reasons for this disparity include that the attentional demands from self-care activities related to chronic disease in HF patients did not decrease, so HF patients experienced more attentional fatigue and showed little improvement, and lower SpO_2 levels in HF patients still existed and may have affected their attention performance. Baseline data showed that perceived attentional demands and lower systemic oxygen saturation levels were associated with poorer attention in some of the attention tests. This suggests that both physiological changes and psychological burden from HF may lead to decreased attention. The NRE intervention in this study, however, did not have components reducing either attentional demands or improving oxygenation for HF patients. In addition, perhaps the NRE intervention may not generate best results when patients are not adequately oxygenated. These factors may potentially explain the smaller impact of NRE interventions in people with disease, especially HF.

The findings on influences of preferences were interesting. More positive preferences were not significantly correlated with improved attention in a previous study, although the preferences were more positively related to the nature pictures than to the urban pictures.[35] The role of preferences was not clearly addressed in Attention Restoration Theory. However, preferences may moderate the impact of the NRE intervention on improved attention. The core elements of NRE intervention (ie, feelings of being away, soft fascination, extended feelings, and compatibility) were closely related to the favorability of environment, and this close relationship may explain how preferences predicted attention improvement.[14]

Similar to the study by Berman and colleagues,[35] mood, a secondary outcome of our NRE intervention, did not change in either the HF patients or in healthy young adults. In contrast, NRE interventions with physical activity in a real natural environment (walking in the park vs walking in a downtown area) improved mood among healthy young adults and patients with mood disorder.[35] Attention Restoration Theory does not describe the relationship between a physical activity component and attention improvement, but nature in reality rather than a virtual environment may intensify the feelings of being away or fascination and enhance immersion to the natural environment by embracing multiple sensory stimulations, including auditory, olfactory, and somatic. Another consideration with mood is its measurement. Surprisingly, the mood status measure with PANAS did not show significant differences between HF and healthy adults, despite the fact that HF patients are more likely to have a higher prevalence of negative moods such as depressive symptoms and anxiety.[38] With the PANAS measuring diverse aspects of mood, scores on positive and negative moods did not show normal distributions. Thus, administering different measures of mood status that are focused on a specific mood such as depressive symptoms might have led to different results. There is also the possibility of selection bias because participants were recruited from an academic medical center that provides optimal care for depression. Thus, individuals with poorer moods might be less likely to enroll in research studies, although they might have more potential to improve.

There are limitations of the study that should be noted. First, the observed power and estimated effect sizes were small on most of the attention measures possibly because of the small sample size and/or the selection of the active control intervention. The sample size was calculated with effect sizes based on differences between the pretest and posttest in the NRE intervention compared with the urban control intervention in young adults. Although increased variances were added to the sample size calculation, individual differences were still predictive of attention in linear mixed models. The active control intervention was carefully selected based on the Attention Restoration Theory and experimental studies based on the theory; however, the effect of the active control condition compared with usual care without any intervention is not clear. Thus, the control condition may have decreased the true effects of the NRE intervention. Second, only 1 dose of NRE intervention (50 photographs of nature) was provided and examined as a way of improving attention. Multiple doses of the intervention in studies of longer duration will be important to gain knowledge about the optimal dosage of NRE intervention to improve attention, as well as about long-term effects. Third, because of repeated administration of the attention tests over a short period, practice effect was possible and may have influenced in the efficacy of the NRE intervention even after controlling in the statistical analysis. In addition to the practice effect, carryover effect from the crossover design may have influenced the results. The 1-week of washout period was decided based on a previous study that used 1 week of washout among healthy young adults.[35] In addition to the empirical support, theoretically, attention is known to de depleted with everyday use.[14,30] However, the results showed statistically significant differences by the order of the intervention on mood in HF and sustained attention in healthy controls. Future studies may need to be designed with a longer washout period when a crossover design is used with the same interventions.

In conclusion, the NRE intervention was feasible in HF patients whose mean age was 59.6 years, which is older than previous studies. This study did not provide preliminary support for the efficacy of the NRE intervention in improving attention and mood among HF patients; however, support was provided that attention can improve with the NRE intervention, especially sustained attention. Healthy adults were better able to maintain their attention switching skills compared with HF patients. These results might indicate that improving attention with NRE intervention is possible among patients with chronic disease even after a decrease in attention due to pathophysiological changes, but the amount of improvement may be smaller than in people without HF. More enhanced NRE interventions (eg, increased intervention time, multiple doses, and different intervention mode with immersive technologies) with a larger sample size will provide more

What's New and Important

- HF patients had relatively worse directed and sustained attention at baseline.
- In a pooled sample, the NRE intervention efficacy on attention was supported.
- Having HF was related to poorer attention switching after the control intervention.

solid results regarding the intervention efficacy in HF patients.

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