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Comparing the effects of different individualized music interventions for elderly individuals with severe dementia

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ABSTRACT

Background: Individuals with dementia often experience poor quality of life (QOL) due to behavioral and psychological symptoms of dementia (BPSD). Music therapy can reduce BPSD, but most studies have focused on patients with mild to moderate dementia. We hypothesized that music intervention would have beneficial effects compared with a no-music control condition, and that interactive music intervention would have stronger effects than passive music intervention.

Methods: Thirty-nine individuals with severe Alzheimer's disease were randomly and blindly assigned to two music intervention groups (passive or interactive) and a no-music Control group. Music intervention involved individualized music. Short-term effects were evaluated via emotional response and stress levels measured with the autonomic nerve index and the Faces Scale. Long-term effects were evaluated by BPSD changes using the Behavioral Pathology in Alzheimer's Disease (BEHAVE-AD) Rating Scale .

Results: Passive and interactive music interventions caused short-term parasympathetic dominance. Interactive intervention caused the greatest improvement in emotional state. Greater long-term reduction in BPSD was observed following interactive intervention, compared with passive music intervention and a no-music control condition.

Conclusion: Music intervention can reduce stress in individuals with severe dementia, with interactive interventions exhibiting the strongest beneficial effects. Since interactive music intervention can restore residual cognitive and emotional function, this approach may be useful for aiding severe dementia patients' relationships with others and improving QOL. The registration number of the trial and the name of the trial registry are UMIN000008801 and "Examination of Effective Nursing Intervention for Music Therapy for Severe Dementia Elderly Person" respectively.

Key words: Alzheimer's disease (AD), behavioral and psychological symptoms of dementia (BPSD), interactive music intervention, passive music intervention, the autonomic nerve index, the Behavioral Pathology in Alzheimer's Disease (BEHAVE-AD) Rating Scale, residual function, cognitive reserve

Introduction

According to the World Health Organization report published in 2012, the estimated number of people living with dementia exceeds 35.6 million worldwide (Alzheimer's Disease International, 2009). This number is predicted to double by 2030, and more than triple by 2050 (Alzheimer's Disease International, 2009). Patients with cognitive impairment typically experience poor quality of life (QOL), associated with a reduced threshold for handling stressful environmental influences as well as behavioral and psychological symptoms of dementia (BPSD) due to physiological, psychological, and emotional factors. Moreover, BPSD also increases caregiver burden, and these problems typically worsen as dementia becomes more severe (Hall and Buckwalter, 1987; Katona *et al.*, 2007; Cerejeira *et al.*, 2012). Various non-pharmacological approaches are used to treat BPSD, and many studies have examined the effects of music intervention as a treatment approach. However, most studies have focused on individuals with mild to moderate dementia, so the effectiveness of music among patients with severe dementia remains unclear.

Several previous music intervention studies have tested the effects of hearing live music, engaging in group singing or playing an instrument, or exposure to music through speakers (Vink *et al.*,

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2011). However, because of severe cognitive dysfunction, patients with severe dementia may have difficulty engaging in music-related activities and expressing emotion. Furthermore, no effective long-term treatment for dementia has been established, and symptoms typically worsen progressively (Boller *et al.*, 2002). For elderly patients with severe dementia, the importance of an interactive component (such as participation in a musical performance), rather than passive music intervention alone, is currently under debate (Holmes *et al.*, 2006; van der Vleuten *et al.*, 2012).

Previous studies have reported that patients with dementia have difficulty in receiving, processing, and responding to environmental stimuli, suggesting that BPSD are influenced by an interaction of environmental stimuli that lower patients' stress thresholds. To explain this phenomenon, Hall and Buckwalter (1987) proposed the Progressively Lowered Stress Threshold Model (Hall and Buckwalter, 1987). In accordance with Hall and Buckwalter's model, Gerdner (2000) reported that agitation and stress were reduced by listening to familiar "individualized music" that evoked positive emotions in patients with severe dementia, eliciting recall of pleasant memories. In their study, they defined individualized music as music that has been integrated into person's life, chosen on the basis of personal preference (Gerdner and Swanson, 1993). Another study reported that, in healthy subjects, the autonomic nervous system becomes activated when listening to music that is self-selected to evoke joy, resulting in the release of dopamine (Salimpoor *et al.*, 2011). Moreover, a study of elderly individuals (healthy or with mild dementia) reported that autobiographical memories are elicited by popular music that evokes emotions (Schulkind *et al.*, 1999; Irish *et al.*, 2006).

Although there have been several reports that music therapy is an effective intervention for elderly dementia patients, few studies have taken a systematic and objective approach (Koger *et al.*, 1999). A Cochrane Collaboration report has noted that further study is required to investigate different treatment effects of passive music listening and active music intervention (Vink *et al.*, 2011).

Systematically evaluating the effects of music intervention on elderly dementia patients is important for assessing various interventional approaches (Holmes *et al.*, 2006; Vink *et al.*, 2011). When examining improvements in QOL of patient and/or caregiver, it is important to establish quantitative evidence for the utility of music intervention for reducing BPSD.

In the current study, we examined differences in the short- and long-term effects of passive and interactive approaches using individualized music associated with special memories to evoke positive emotions and recollection in elderly individuals with severe dementia. We hypothesized that individualized music intervention would have beneficial effects compared with a no-music control condition, and that the effects of interactive music intervention would be greater than the effects of passive music intervention.

Methods

Participants

We recruited 127 participants with dementia from four group homes and a special dementia hospital in Kobe City. Of these, 39 participants met the following eligibility criteria: Alzheimer's-type dementia according to the diagnostic criteria specified in the Diagnostic and Statistical Manual of Mental Disorders, 4th edition (American Psychiatric Association, 1994); severity was classified at level 3, indicating severe dementia as specified by the Clinical Dementia Rating Scale (Morris, 1993); no hearing disorders that could prevent participants from listening to music; no experience of playing musical instruments; aged 65 years or more; and no history of heart disease, hypertension, or diabetes (because changes in autonomic nervous system were used as an index). Cognitive function was evaluated using the Mini-Mental State Examination (MMSE; Folstein *et al.*, 1975).

Study design

We compared a non-intervention Control group, a Passive music intervention group, and an Interactive music intervention group. Each intervention was performed for 30 min once a week for 10 weeks (10 sessions in total).

We took steps to minimize the effect of confounding variables in the intervention groups. Participants were randomly and blindly assigned to either Control, Passive, or Interactive group using stratified randomization (gender and MMSE level).

In order to minimize the confounding effects of testing environment, all participants were examined individually in a familiar room. In the Control and Passive groups, a caregiver and music provider observed participants from a distance without directly interacting with them. In the Interactive group, the intervention session was conducted individually by a music facilitator who directly interacted with each participant. In addition, we counterbalanced the assignment of music facilitators to participants to avoid the potential effects of music facilitators' individual traits, and to reduce any potential bias resulting from a music facilitator testing the same participants more than once. Moreover, to reduce the influence of feeding and arousal level on the autonomic nervous system, all interventions were conducted from 10:00–11:00 am. The primary experimenters were not involved in the intervention or evaluation, and the evaluators did not act as music facilitators.

Music stimulation

To select the music in the intervention, we first analyzed participants' behavior to determine the period of their life that was recalled most frequently. After closely interviewing each participant and their family, we selected individualized music that was related to special memories for each participant. Specifically, we selected music that was likely to evoke positive emotions such as pleasure or joy (Ikeda *et al.*, 1998; Schulkind *et al.*, 1999; Gerdner, 2000; Salimpoor *et al.*, 2011).

Procedure

Each Control group participant spent time with one caregiver in their own room as usual, without any music intervention (silent environment). The Passive group participants passively listened to the selected music via a CD player. The Interactive group participants not only listened to the selected music via a CD player but also participated in interactive activities (e.g., clapping, singing, and dancing) guided by a music facilitator. The music facilitators included two music therapists, four occupational therapists, and six nurses with knowledge of severe dementia symptoms. Each of these specialists was trained by experimenters for one week to facilitate the interactive music intervention, then conducted five days of practical training. The music facilitators watched the participants before intervention and determined each participant's level of cognitive function and BPSD characteristics. The facilitators confirmed that the music was suitable in terms of engaging the participants and eliciting a joyful emotional state, directed the participants' attention to the music, and used an interactive approach that responded to the participants' emotional reactions to the music.

This study was conducted in accordance with the Declaration of Helsinki (revised at the General Assembly in Seoul in 2008; see World Medical Association, 2008) and approved and registered by the ethical committee of Kobe University Graduate School/School of Medicine, Japan (registration number 498).

Evaluation

The short- and long-term effects of intervention were evaluated by two trained occupational therapists and four trained nurses in a blinded fashion.

Short-term effects

We systematically measured indices of BPSD that influence emotion and stress levels 5 min before and 5 min after each of the 10 music intervention sessions, using the autonomic nerve index and the Faces Scale. The Faces Scale is a tool commonly used by psychologists and healthcare professionals to assess emotions. Patients suffering from severe dementia cannot verbally express their emotions, necessitating the use of the Faces Scale to evaluate their positive or negative facial expressions. This scale enables the objective evaluation of a subject's emotional state (as in McKinley *et al.*, 2003 and Pautex *et al.*, 2006). The short-term effects of intervention were evaluated by two trained nurses in a blinded fashion. Heart rate (HR) is reported to be affected by the autonomic nerve system (Akselrod *et al.*, 1981; Yodlowski *et al.*, 1998), decreasing when the parasympathetic nervous system activity is dominant and sympathetic nerve activity is decreased, and increasing when the parasympathetic nerve activity is decreased and sympathetic nerve activity is dominant. However, measuring HR alone cannot distinguish sympathetic from parasympathetic regulation of the heart. Since the parasympathetic nerve activity changes with respiration, HR also fluctuates with respiration. By analyzing the fluctuation of HR (i.e., HR variability (HRV) measured in milliseconds (ms)) in the frequency domain, the parasympathetic activity (high-frequency HF) component of HRV can be estimated (Akselrod *et al.*, 1981; Yodlowski *et al.*, 1998). Similarly, emotional state affects HR through activation of both sympathetic and parasympathetic nerves, but it takes some time and thus results in slower HR fluctuation. This slower HR fluctuation is referred to as the low-frequency (LF) component of HRV. As such, LF is mediated by both systems, and does not adequately reflect differences in inter-individual variation of sympathetic nerve activity (Pagani *et al.*, 1988). Therefore, we employed HF and HR as stress indices and measured them before and after each music intervention. The maximum entropy method was used for HRV spectrum analysis. In addition, we used the Faces Scale to assess participants' emotional condition as autonomic nervous activity changed (ranging from 1 to 5, where 5 represents "extremely comfortable").

Long-term effects

The long-term effects of music intervention were evaluated by changes in BPSD that are known to be directly linked to the QOL of elderly individuals with dementia and their caregivers (Katona *et al.*, 2007; Cerejeira *et al.*, 2012). The Behavioral Pathology in Alzheimer's Disease (BEHAVE-AD) Rating Scale was used to evaluate BPSD within two weeks (Reisberg *et al.*, 1987). Symptomatic categories were classified into the following seven items: (1) paranoid and delusional ideation, (2) hallucinations, (3) activity disturbance, (4) aggressiveness, (5) diurnal rhythm disturbance, (6) affective disturbance, and (7) anxieties and phobias. In addition, global ratings were used to evaluate caregiver burden.

The BEHAVE-AD evaluations were conducted two weeks prior to the study (baseline), after the final music intervention (after 10 music intervention sessions), and three weeks after the intervention ended. In order to evaluate participants' behavior, blinded evaluators (two trained occupational therapists and two trained nurses) who did not work in the study institution observed the participant's behavior and recorded only the important changes in BPSD.

In addition, we videotaped participants' behavior during music intervention, and calculated the number of minutes of behavior, indicating that participants were responding to music intervention in the Passive and Interactive groups. These behaviors included singing a song, keeping time, clapping to the beat, inserting an interlude, dancing, displays of affective response, including laughter, and intervention-related speech. We excluded the item "Whether the participant was lost in music or not," which is difficult to judge objectively. The response of the Control group could not be tested in this way because they did not undergo music intervention.

Statistical analyses

Short-term effects

In order to assess changes in the stress level, we compared values before intervention with those after intervention. The autonomic nervous system indices (HR and HF) were averaged to determine mean values for each group.

Heart rate changes were analyzed using two-way repeated-measures analysis of variance (ANOVA). Since HF was not normally distributed (the Kolmogorov–Smirnov test, $p < 0.05$), comparisons were made within the same group using the Wilcoxon signed-rank test. For comparisons between groups, the value at rest before music intervention was defined as the baseline, and autonomic nervous system index values showing significant individual differences were converted to a measure of each participant's rate of change, and then analyzed using one-way ANOVA. Post hoc analyses were performed using the Tukey's Honestly Significant Difference test. Values were considered statistically significant at $p < 0.05$.

For the Faces Scale, comparisons were made within the same groups using the Wilcoxon signed-rank tests. For comparisons between groups, a multiple comparison was conducted using the Mann–Whitney *U* test followed by the Bonferroni correction (statistical significance level of $p < 0.0167$).

Long-term effects

Intra-group comparisons were made using the Wilcoxon signed-rank tests because BEHAVE-AD is an ordinal ranking scale. For the baseline versus after 10 music intervention sessions comparison, and the comparison after 10 music intervention sessions versus three weeks after music intervention, multiple comparisons were conducted using the Mann–Whitney *U* tests followed by the Bonferroni correction (statistical significance level of $p < 0.025$).

The length of reaction period (in minutes) in response to music intervention was measured by analyzing the video footage. The length of the reaction period was averaged for the first half (the first to fifth) and the second half (the sixth to tenth) of the music intervention sessions. Because the values were not normally distributed in the Passive and Interactive groups, both intra-group and inter-group comparisons were made using the Mann–Whitney *U* tests (statistical significance level of $p < 0.05$).

Data were analyzed using the SPSS software statistical package (version 20.0, SPSS Inc, USA).

Results

Participants' demographic characteristics were as follows: Control group (11 women, 81 ± 8.3 years old; two men, 84.5 ± 4.95 years old; MMSE, 4.7 ± 3.9), Passive group (10 women, 81.1 ± 11.0 years old; three men, 78.7 ± 12.1 years old; MMSE, 4.7 ± 4.8), and Interactive group (11 women, 81.2 ± 7.5 years old; two men, 76 ± 7.1 years old; MMSE, 4.6 ± 3.5). The medication regimen was not changed during the study period for any of the participants, and none of the participants dropped out.

Short-term effects

The analyses of the short-term effects are shown in Tables 1 and 2, and Figures 1 and 2. In the Passive group, the comparison of the autonomic nervous system indices (HR and HF) before and after music

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Table 1. Short-term effects of music intervention on HR, HF, and Faces Scale

	HR			HF			FACES SCALE		
	TWO-WAY REPEATED MEASURE ANOVA			WILCOXON SIGNED-RANK TEST			WILCOXON SIGNED-RANK TEST		
INTERVENTION MUSIC SESSION	BEFORE MEAN (SD)	AFTER MEAN (SD)	p-VALUE	BEFORE MEAN (SD)	AFTER MEAN (SD)	p-VALUE	BEFORE MEAN (SD)	AFTER MEAN (SD)	p-VALUE
Control group (n = 13)	74 (11.4)	75 (11.2)	0.08	120.1 (68.1)	82 (32)	0.002**	3.0 (0.6)	2.9 (0.5)	0.58
Passive group (n = 13)	79 (10.6)	78 (9.7)	0.001**	108.2 (103.6)	144.6 (103.2)	0.009**	3.0 (0.8)	3.4 (0.7)	0.021*
Interactive group (n = 13)	76 (13.7)	74 (13.4)	0.00**	128.4 (59.1)	185 (115.9)	0.005**	3.1 (0.7)	4.1 (0.8)	0.001**

*p < 0.05, **p < 0.01.

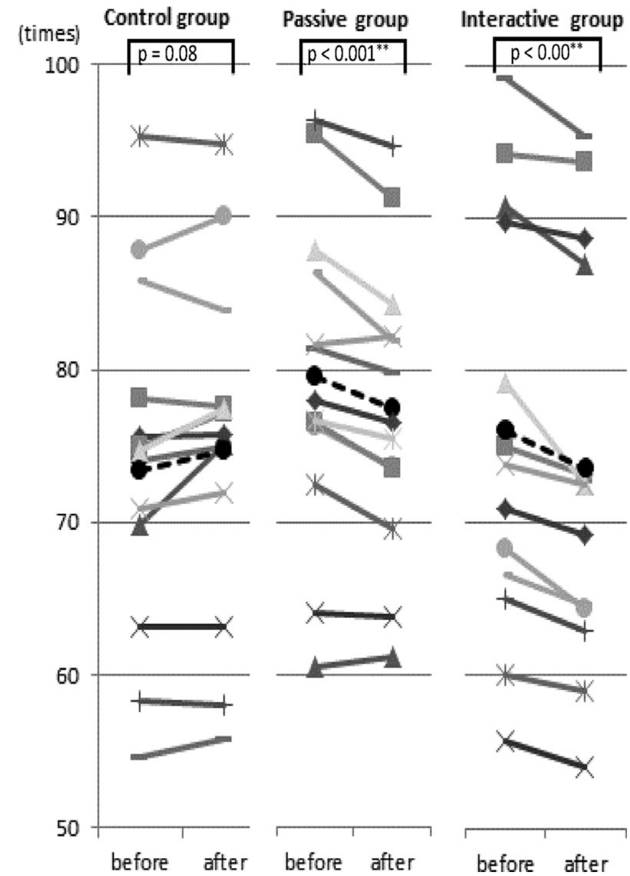

Figure 1. Effect of music intervention on heart rate. Black circles and dotted lines represent mean values. The two-way repeated-measure ANOVA was used to calculate the p-values.

intervention revealed that the parasympathetic nerve activity became dominant (HR, $F(1, 36) = 4.968$, $p < 0.01$; HF, Z–2.6, $p < 0.01$). Similarly, in the Interactive group, the parasympathetic activity became dominant after moderate activity by a music facilitator (HR, $F(1, 36) = 4.968$, $p < 0.01$; HF, Z–2.8, $p < 0.01$). In the Control group, HR did not change ($F(1, 36) = 4.968$, $p = 0.08$), and HF was increased (Z –3.1, $p < 0.01$), but the sympathetic nerve activity was not sufficiently dominant to alter HR. Analysis of the Faces Scale assessment revealed no difference in the Control group before or after intervention (Z–1.9, $p = 0.6$). In contrast, patients in the Passive group were in a significantly more comfortable mood after the intervention compared with before the intervention (Z–2.3, $p < 0.01$), and patients in the Interactive group exhibited an even greater improvement in the emotional state among the three groups (Z –3.2, $p < 0.01$).

Long-term effects

Long-term effects were results of comparing the baseline versus after 10 intervention sessions,

Table 2. Comparison between groups on HR, HF, and Faces Scale

	HR RATE OF CHANGE ONE-WAY ANOVA	HF RATE OF CHANGE ONE-WAY ANOVA	FACES SCALE VALUE OF CHANGE MANN-WHITNEY
MUSIC SESSION	MEAN (SD)	MEAN (SD)	MEAN (SD)
Control group (n = 13)	0.02 (0.03)[a]	−0.3 (0.2)[d] -	−0.1 (0.2)[g]
Passive group (n = 13)	−0.02 (0.02)[b]	0.7 (1.0)[e]	0.3 (0.4)[h]
Interactive group (n = 13)	−0.03 (0.02)[c]	1.0 (0.7)[f]	1.1 (1.5)[i]

HR, Tukey's HSD ($F(2,36) = 15.2$, $^{*}p < 0.05$, $^{**}p < 0.01$).
[a]Control group vs Passive group, $^{**}p < 0.01$.
[b]Control group vs Interactive group, $^{**}p < 0.01$.
[c]Passive group vs Interactive group, $p = 0.66$.
HF, Tukey's HSD ($F(2,36) = 11.5$, $^{*}p < 0.05$, $^{**}p < 0.01$).
[d]Control group vs Passive group, $^{**}p < 0.003$.
[e]Control group vs Interactive group, $^{**}p < 0.00$.
[f]Passive group vs Interactive group, $p = 0.56$.
Faces Scale; ($^{*}p < 0.0167$).
[g]Control group vs Passive group, $U = 33$, $^{*}p < 0.007$.
[h]Control group vs Interactive group, $U = 0$, $^{*}p < 0.00$.
[i]Passive group vs Interactive group, $U = 16$, $^{*}p < 0.00$.

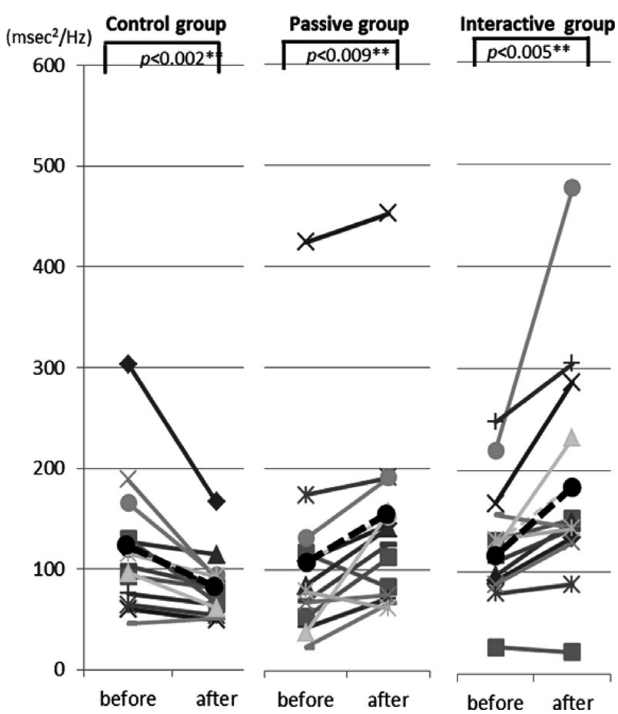

Figure 2. Effect of music intervention on high-frequency component. Black circles and dotted lines represents means values. The Wilcoxon signed-rank test was used to calculate the p-values.

the after 10 intervention sessions versus three weeks after intervention, and multiple comparisons. The mean values and analysis of the BEHAVE-AD subscores from each group are shown in Table 3. Regarding the effects of music intervention on BPSD, the scores of two items (affective disturbance, Z –2.3, $p < 0.025$; anxieties and phobias, Z –2.3, $p < 0.025$) were reduced in the Passive group whereas five items (affective disturbance, Z –2.3, $p < 0.025$; anxieties and phobias, Z –2.3, $p < 0.025$; paranoid and delusional ideation, Z –2.7, $p < 0.025$; aggressiveness, Z –2.6, $p < 0.025$; and activity disturbance, Z –2.5, $p < 0.025$) and the Global Rating indicating caregiver burden were reduced (Z –2.4, $p < 0.025$) in the Interactive group. In the Control group, only activity disturbance (Z –2.5, $p < 0.025$) and affective disturbance were increased (Z –2.4, $p < 0.025$). In contrast, three weeks after music intervention BPSD had significantly increased in both the Passive and Interactive groups after the sessions had ceased ($p < 0.025$). The Control group exhibited no changes in BPSD at three weeks after the intervention ($p = 0.025$).

Behavior during the music intervention sessions was videotaped, and we calculated the number of minutes of behavior indicating that participants were responding to music intervention in the Passive and Interactive groups. In the Passive group, the measured behavioral responses during music intervention were not significantly different between the first (mean: 17.6 min, SD: 12.5, median (Mdn): 21.4) and second halves of the intervention period (mean: 18.7 min, SD: 13.9, Mdn: 27.5; $Z = -1.58$, $p = 0.05$).

In the Interactive group, the reaction period was significantly longer in the second half of the intervention (mean: 28.4 min, SD: 5.8, Mdn: 30) compared with the first half (mean: 26.9 min, SD: 7.6, Mdn: 29.6; $Z = -2.5$, $p < 0.05$). Moreover, both sets of reaction periods were significantly longer in the Interactive group compared with the Passive group (the first half, $U = 31$, $p < 0.05$; the

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Table 3. Changes in the scores of Behavior Pathology in Alzheimer's Disease (BEHAVE-AD) Rating Scale

	Control group (n = 13)		Passive group (n = 13)		Interactive group (n = 13)	
BEHAVE-AD	Mean (SD)	p-value	Mean (SD)	p-value	Mean (SD)	p-value
Paranoid/delusional ideation						
Before intervention	2.2 (2.1)		2.1 (2.9)		2.1 (2.1)	
After 10th intervention	2.1 (2.4)	0.8	0.8 (1.7)	0.03	0.9 (1.5)	0.01*
3 weeks after	2.7 (2.5)	0.2	1.9 (2.4)	0.03	2.2 (1.7)	0.01*
Hallucination						
Before intervention	1.2 (1.7)		0.7 (1.2)		2 (3.0)	
After 10th intervention	1.6 (1.9)	0.3	0.2 (0.6)	0.06	0.5 (1.0)	0.05
3 weeks after	1.4 (2.0)	1.0	0.6 (1.2)	0.2	1.9 (2.5)	0.03
Activity disturbances						
Before intervention	2.3 (1.8)		2.3 (2.0)		3 (2.4)	
After 10th intervention	3.5 (1.8)	0.01*	1.6 (1.5)	0.1	1.2 (1.1)	0.01*
3 weeks after	3.7 (1.8)	0.4	2.2 (1.5)	0.1	2.9 (1.9)	0.01*
Aggressiveness						
Before intervention	2.5 (3.1)		1.5 (1.8)		2.5 (2.4)	
After 10th intervention	3.2 (3.0)	0.4	1.5 (0.9)	1	0.7 (1.0)	0.01*
3 weeks after	2.9 (3.1)	0.5	1.3 (2.0)	0.4	2.5 (2.2)	0.01*
Diurnal rhythm Disturbances						
Before intervention	0.4 (0.7)		0.1 (0.3)		0.5 (0.9)	
After 10th intervention	0.5 (0.9)	0.3	0.3 (0.8)	0.3	0.5 (0.9)	0.6
3 weeks after	0.4 (0.8)	0.3	0.1 (0.3)	0.3	0.5 (0.9)	0.6
Affective disturbances						
Before intervention	1.1 (1.2)		1.2 (1.2)		0.9 (1.1)	
After 10th intervention	2.2 (1.7)	0.02*	0.5 (0.7)	0.02*	0.3 (0.6)	0.02*
3 weeks after	2.2 (1.7)	1.0	1.3 (1.0)	0.02*	1.1 (1.0)	0.02*
Anxieties and phobias						
Before intervention	1.1 (1.49)		1.2 (1.8)		1.1 (1.3)	
After 10th intervention	1.2 (1.7)	0.1	0.5 (0.5)	0.02*	0.3 (0.6)	0.01*
3 weeks after	1 (1.1)	0.3	1 (1.3)	0.01*	1.1 (1.4)	0.02*
Global Rating						
Before intervention	1.3 (0.7)		0.9 (0.5)		1.5 (0.7)	
After 10th intervention	1.5 (0.8)	1.0	0.8 (0.4)	0.4	0.7 (0.6)	0.01*
3 weeks after	2.2 (0.9)	0.03	1.1 (0.5)	0.2	1.2 (0.6)	0.08

*$p < 0.025$.

second half, $U = 38$, $p < 0.05$). Although there were differences in response period, participants in both groups were observed clapping their hands to the beat or singing along. Both intervention groups also clearly expressed emotion, including laughter, joy, or reminiscence. However, one participant with hyperkinesis and three participants exhibiting severe apathy or significantly reduced attention in the Passive group did not exhibit clear responses to music intervention. Other participants reacted sporadically, even when the intervention was repeated for many times. In the Interactive group, one patient with hyperkinesis exhibited increased reaction time as the intervention proceeded: 2 min of reaction period in the first to sixth sessions, 7 min of reaction in the seventh session, and 18.1 min in the tenth session. Three other patients exhibited shorter reaction periods during the first half of music intervention compared with the second. The rest of the participants exhibited comparable reaction times across all the music sessions.

Discussion

Short-term effects

The current results revealed that both Passive and Interactive interventions involving individualized music associated with special memories reduced stress and increased relaxation in individuals with severe dementia immediately after intervention, compared with participants in the no-music control condition.

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In addition, the Faces Scale assessment revealed that both music interventions elicited pleasant emotional states to a significant extent compared with the Control condition. Interestingly, parasympathetic nervous system activity significantly increased in the Interactive group (but not in the Passive group) following the intervention, even though subjects had actively participated during the session. We propose that the parasympathetic nervous system activity became dominant after the interactive intervention in the current study, even though participants were more active, because the musical stimulation in the intervention evoked positive emotions and reduced stress.

The reduction in stress that we observed among patients with severe dementia in response to an interactive music intervention is particularly relevant for care practice because interactions between environmental stimuli have previously been reported to influence BPSD due to patients' lowered stress thresholds (Hall and Buckwalter, 1987). In addition, patients with communication disorders and reduced cognitive function typically have difficulty relieving stress on their own.

Taken together, our results indicate that the short-term effects of interactive participation in an activity using individualized music associated with special memories include decreased stress and increased positive emotional response. Both of these effects may improve QOL and increase activity in daily life among elderly individuals with severe dementia.

Long-term effects

The BEHAVE-AD assessment indicated that BPSD associated with "affective disturbance" and "anxieties and phobias" functions were reduced in both Interactive and Passive music intervention groups in accordance with the findings of Gerdner's (2000) study of individualized music intervention. In the Passive group in the current study, the intervention was found to reduce stress, induce laughter, and evoke positive memories. These findings indicate that listening to music stimulated cognition in an elderly population with severe dementia, in accordance with previous reports (Sacks, 2006).

The Interactive group exhibited reduced scores for five items on the BEHAVE-AD assessment (affective disturbance, anxieties and phobias, paranoid and delusional ideation, aggressiveness, and activity disturbance). In addition, the Global Rating scores indicated reduced caregiver burden. A significant reduction in BPSD was also observed following interactive intervention, compared with passive music intervention and a no-music control condition. These changes were observed two weeks from the end of the intervention, but had disappeared by three weeks after the intervention period, indicating that the intervention should be regularly conducted to exert continued beneficial effects.

In contrast, the control group exhibited increased BPSD at the end of the intervention period, possibly because of further deterioration causing a decrease in stress thresholds for physiological, psychological, and emotional factors (Hall and Buckwalter, 1987; Katona *et al.*, 2007; Cerejeira *et al.*, 2012).

The videotape results in the Interactive group indicated that the duration of behavioral responses to music increased with each music intervention session, suggesting that residual function, as indicated by the performance of activities and person-to-person contact, was restored by music intervention. These results are in accordance with previous reports of the effectiveness of music intervention for evoking emotion and improving cognitive focus (Sacks, 2006).

The current findings suggest that the interactive music intervention may directly stimulate cognitive and emotional function in individuals with cognitive reserve in accordance with the previous reports of an association between the severity of BPSD and residual function due to cognitive reserve in elderly patients with severe dementia (Stern, 2009; Yamaguchi *et al.*, 2010). Although emotional functioning is reported to remain relatively intact until the very late stages of the disease (Ikeda *et al.*, 1998), aspects of cognitive dysfunction, such as reduced attention or memory impairment, could inhibit environmental recognition and reduce the ability to communicate. As a result, elderly individuals with severe dementia cannot easily perform activities spontaneously and tend to withdraw from their surroundings (Boller *et al.*, 2002). Therefore, it is important to focus on the patients' remaining emotional functions as a way of stimulating cognitive function (Boller *et al.*, 2002; Stern, 2009; Yamaguchi *et al.*, 2010). Overall, these findings indicate that interactive music intervention may be effective in restoring relationships between severe dementia patients and other people, leading to improved QOL.

The Interactive music intervention was found to effectively reduce BPSD, including paranoid and delusional ideation, activity disturbance, and aggressiveness toward caregivers. These changes resulted in reduced care burden, which has been found to lead to improved caregiver QOL (Miyamoto *et al.*, 2010; Huang *et al.*, 2011). Although it is often difficult for caregivers to facilitate laughter, joy, and memory recall in elderly patients with severe dementia, the results of the current study demonstrate that music intervention, particularly interactive music intervention, can provide a useful and effective caregiving tool.

Limitations and strengths of the current study

The current study has several limitations that should be considered. First, we did not test the optimal time for conducting interventions, and only measured the effects of intervention up to three weeks after the end of the intervention period. Future studies should vary the length of interventions to determine the most effective duration, and should include a longer follow-up period. In addition, we only examined individual music intervention, but did not compare it with the effects of group intervention. Finally, the sample size of the current study was small, because we had to tightly control for confounding factors and exclude comorbid conditions. Future studies with larger sample sizes will be needed to address these limitations. Furthermore, we only tested patients with severe dementia. It would be useful for future studies to also test the effects of active and passive music intervention in patients with mild dementia. Despite these limitations, the current study established quantitative evidence for the utility of music intervention for reducing BPSD in patients with severe dementia.

Conclusion

In conclusion, the current results suggest that both passive and interactive music interventions can reduce stress and induce relaxation in individuals with severe dementia. In addition, a reduction in BPSD was found two weeks after the intervention period in the Interactive and Passive music intervention groups, but not in the Control group. This reduction in BPSD in the Interactive group was more than that in the Passive group. However, it should be noted that this BPSD reduction in both intervention groups disappeared three weeks after the intervention period, indicating that the intervention should be continued at regular intervals to exert maintained beneficial effects. Overall, since interactive music intervention restored residual cognitive and emotional functions, these findings indicate that this approach may be useful in aiding severe dementia patients' relationships with others.

Conflict of interest

None.

Description of authors' roles

Mayumi Sakamoto formulated the research questions, designed the study, analyzed the data, and wrote the paper. Hiroshi Ando helped to design the study, supervise data collection, and write the paper. Akimitsu Tsutou helped to supervise the data collection and write the paper.

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