Effects of Sonic Features on the Affective States of Dementia Patients: A Pilot Study

Sylvain Le Groux, Zenon Mathews, Melissa Brotons, Jonatas Manzolli, Patricia Marti, Paul FMJ Verschure

Laboratory for Synthetic, Perceptive, Emotive and Cognitive Systems

Universtitat Pompeu Fabra, Universitat Ramon Llull

Barcelona

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Abstract

Although music is widely used in therapeutic settings, the precise relationship between musical parameters and affective states is not clear. To address this issue in the context of Alzheimer disease (AD) we developed an automated test procedure that assesses the correlation between the timbre, spectral content, intensity, tempo and consonance of a set of parametrized sound samples with the self-reported emotional state of AD patients. Our results show that the control and patient groups had significantly different emotional reactions to the sound samples, suggesting possible applications in automatic AD diagnosis. We found that the timbre characteristic of a sound had a direct impact on the reported emotional state of the patients. Synthetic sounds and voices were reported to be sad and relaxing while the voice was perceived as unpleasant. Higher levels in the sound features entailed a more stressful response from the patients. Since specific characteristics of the sound seem to trigger specific emotional response, we could use those correlations as a means to induce soothing emotional states in AD patients.

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Dementia can be defined as a progressive loss of mental function which results in a restriction of daily activities and in most cases leads in the long term to the need for care (Kurz, 2007). Given the increased life expectancy in the western world, the total number of Alzheimer Disease (AD) patients will increase while also their fraction will increase due to a decreased population growth. Although the most common type of dementia is Alzheimer's disease (60-70% of the cases), there are other known types of dementia like the vascular dementia, dementia with Lewy bodies, frontotemporal dementia and the Creutzfeldt-Jakob disease. The common symptoms of dementia are cognitive impairments such as memory impairment, aphasia, apraxia, disorientation and mental slowing accompanied with non-cognitive deficits and behavioral problems (Alzheimer´s association, 2006). The latter are common in more advanced phases of AD including: depression (60-98% of patients), anxiety and agitation (80% of dementia patients), sleeping problems (70% of dementia), and wandering. These behavioral problems appear to be the main cause of carer burden (Coen et al., 1997;Lyketsos et al., 2002;Tremont et al, 2006) and currently the use of restraints is one of the most common choices to deal with problem behavior (Testad et al., 2005). These disorders have a great impact on the duration of inpatient treatment, reduction of self-care and the probability of nursing home placement (Wancata, et al., 2003).

However, the pharmacological treatment of these non-cognitive symptoms is only of limited effect (Sink et al., 2005) and is considered inappropriate due to an increased risk of mortality (www.fda.gov/cder/drug/advisory/antipsychotics.htm). Hence, non-pharmacological interventions to combat the behavioral and psychiatric symptoms of AD are urgently needed. However, currently it is not clear what alternative approaches such as sensory interventions, social contact (real or simulated), behavior therapy, staff training, structured activities, environmental interventions, medical/nursing care interventions, and combination therapies have to offer (Cohen-Mansfield, 2001). Here we investigate the effect of sound properties on the emotional state of AD patients.

The effect of music on stress and anxiety has been established using a variety of self-report, physiological, and observational means (Hanser, 1985; Khalfa et al., 2003). Music therapy can have physiological and psychological benefits on patients with a variety of diagnoses and undergoing differing medical treatments (Standley, 2000), while the effect of music on stress induced arousal has shown consistent results using physiological, behavioral and self-report measures (Pelletier, 2004). Interestingly enough this analysis also suggested that specific musical properties including slow tempo, low pitches, primarily based on string composition excluding lyrics and regular rhythmic patterns without extreme changes in dynamics are more effective than the subject’s preferred music. Music and music therapy has been shown to affect, at different time scales, a number of neuromodulatory and neurohormonal systems that are correlated with depression including 5HT and melatonin (Kumar et al., 1999; Evers et al., 2000). Although these results show great promise, a more recent meta-analysis has shown that strong conclusions cannot be drawn from the literature on music therapy due to a number of methodological problems (Sung & Chang, 2005). The same conclusion was drawn from a meta-analysis of the effect of music therapy on agitation treatment in AD patients (Lou, 2001).

In this paper we focus on the study of a parameterized set of sound samples. We propose to study the effect of subtle sound properties such as timbre, spectral content, tempo, consonance and intensity on the subject’s emotional state. We propose a quantitative psychoacoustic study using self-report measures with well-diagnosed and monitored patient groups to define a foundation on which sonic based therapy can be applied to AD.

Method

Subjects

A total of 65 subjects ranging from 51 to 92 years of age attending two day-care centers in Barcelona participated in this study. Criteria for inclusion in the study included the following: (a) a neurologist diagnosis of dementia, (b) verbal ability sufficient to answer simple social and verbal instructions, and (c) signed consent form to participate in the study. Also 8 healthy adults from the university with an age range from 23 to 30 years old served as control subjects.

Experimental Set-Up

In our experiment, each subject was seated in front of a computer and interacted with custom-made stimulus delivery and data acquisition software, called Zblast . When the experiment started, the subject was exposed to a number of sounds to calibrate the sound level. Subsequently, a number of sound samples with specific sonic characteristics were presented together with a dialog (Fig 1). The subject had to rate each in terms of their emotional content (valence, arousal, anger, pleasantness) using a percentage scale by moving a slider on the screen. The subject was given the possibility to skip samples and a music therapist was available for subjects who had difficulty manipulating the mouse. Each sample was looped for a maximum of 30 seconds or until the subject had responded to all four dialog boxes.

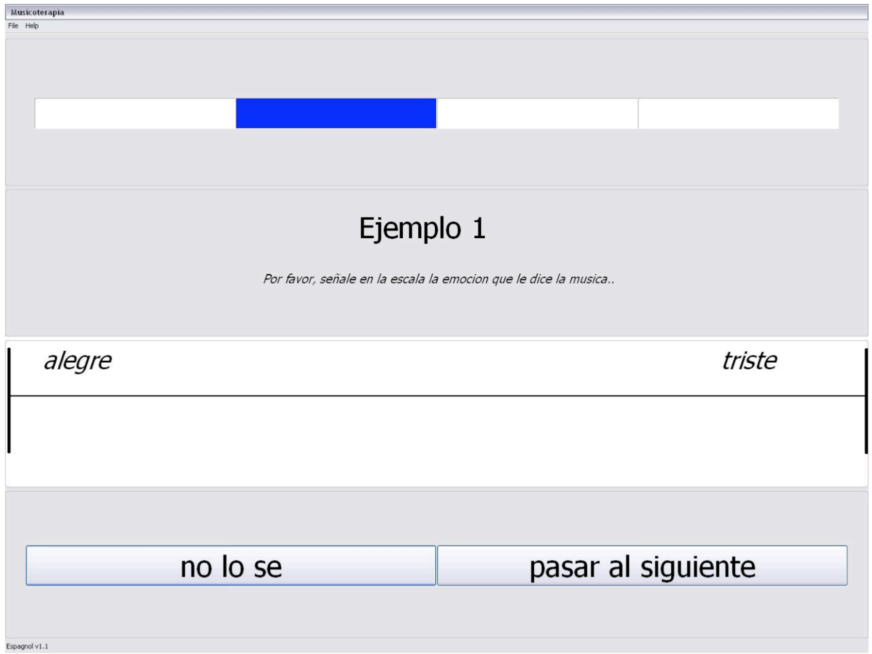

Figure 1: The stimulus delivery and data acquisition system's Graphical User Interface: The user rates the sound sample 1 on a scale from happy to sad based on his/her self-reported emotional state. The user can click the box "no lo se" (I do not know) or "pasar al siquiente" (pass to the next) to skip the next dialog. The blue bar at the top indicates the duration that the sample has played and will play.

Procedure

We investigated a parameterization of musical space by distinguishing a number of sonic categories and their parameters (see Figure 2). Central to this structure is the, so-called, critical band theory of the perception of consonance and dissonance that defines these musical parameters as objective biophysical properties (Fishman et al., 2001; Schreiner et al., 2000).

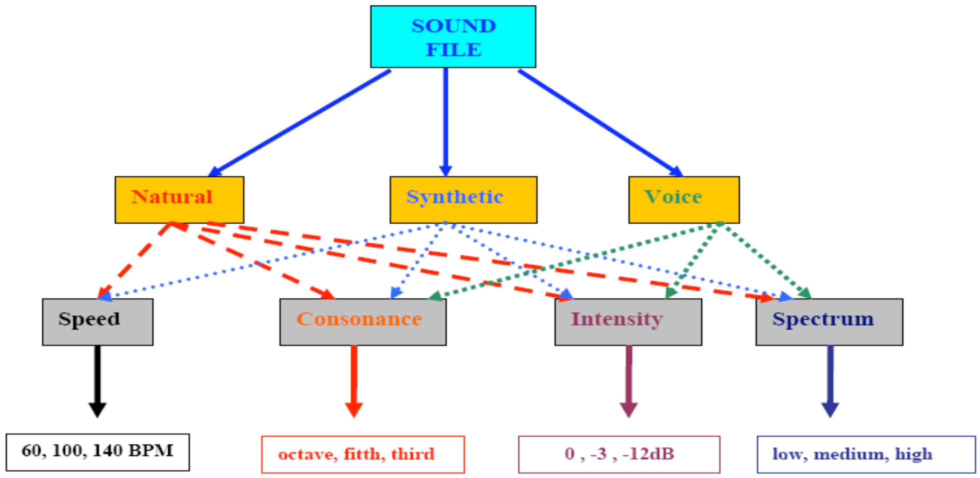

Figure 2: Parametric tree defining the first level musical space that will be explored. See text for further explanation.

We have investigated the influence of different sound features on the emotional state of the patients using a fully automated and computer based stimulus presentation and response registration system. The sound database comprised 75 different sound samples that covered the parameter space depicted in Figure 2. After listening to each sound the patients were asked to give ratings for four main emotional states: happy/sad (Valence from 0 to 100%), relaxed/stressed (Arousal from 0 to 100%), fear/anger, like/dislike (Pleasantness from 0 to 100%).

Preliminary Results

Global Distributions

The observation of global distribution histograms for the control group and the patients shows that the dementia patients have a tendency to be more extreme in their ratings than the controls (See Figure 3 and 4) .We confirm this observation by a multivariate (four emotional state variables) ANOVA analysis on the control and patient groups that yields a value $p<0.05$. The distribution of responses significantly differs between the patient and control groups.

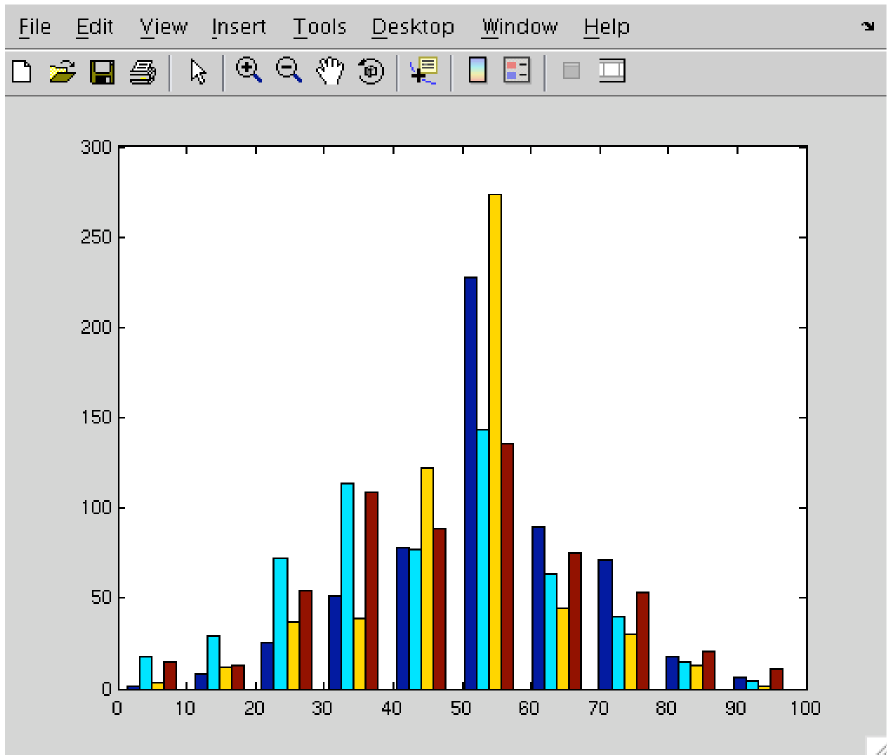

Figure 3: Frequency distribution of the emotional ratings (scale from 0 to 100%) from the control group (N=8). Dark blue stands for valence rating, light blue stands for Arousal, Yellow is Anger and red is pleasantness.

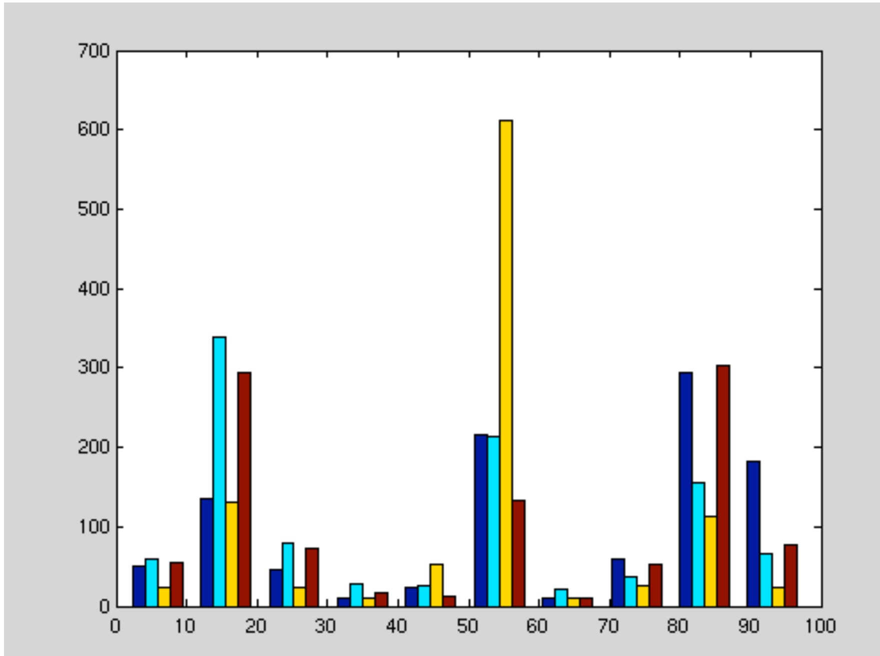

Figure 4: Frequency distribution of the emotional rating ratings (scale from 0 to 100%) from the dementia patients (N=65). Dark blue stands for valence rating, light blue stands for Arousal, Yellow is Anger and red is pleasantness.

Another interesting observation concerns the emotional states themselves. The boxplot of the different emotional states for the control and patient groups suggest that the axis Fear/Anger is perceived as confusing for both the controls and the patients (See Figure 5). It appears that the Fear/Anger state has no correlation with the musical properties. Consequently, in our future analysis we won't consider this axis as being relevant for musical purposes. We also notice that the patients have a tendency to give more sad ratings (score close to 100%) than happy (score close to 0%) on the valence scale (Figure 5, column 1).

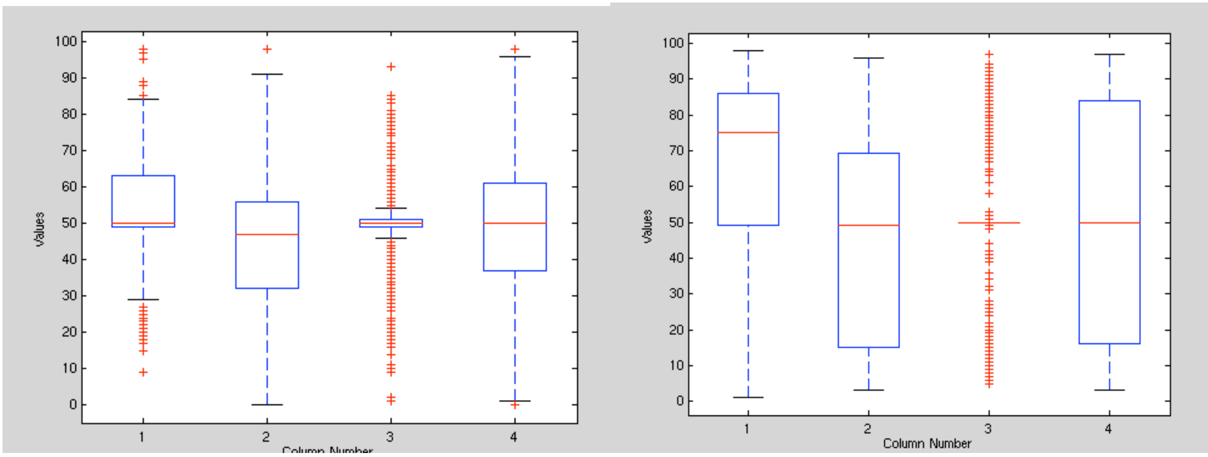

Figure 5: Boxplot of the emotional state ratings (%) for each state (1 is valence, 2 is arousal, 3 is anger and 4 is pleasantness) for the control group (left side) and the patients (right side)

Effect of Sound Features on the Emotional States

In this section of the paper we propose to study in detail the influence of the different sonic features on the subjects self-reported emotional states, and we expose our preliminary results. The three different factors that intervene are the timbre of the sound sample (i.e. its origin: synthetic, natural, voice), the sound features (consonance, speed, intensity, spectrum), and the level of each feature (low, medium, high). We use a three-way analysis of variance (ANOVA) technique to determine the statistical relevance of each of the three factors on the subject's ratings. This analysis is meaningful only for normally distributed data and thus only applies rigorously to our control data (c.f. Figure 3 and 4). Nevertheless failure to meet the normality assumption might not lead to drastically different results (Glass et al. 1972). Hence, to achieve a tentative interpretation we will analyze the patient data using the same method. This should only be taken as a preliminary step towards more complex analysis. Our analysis showed no significant three-way interaction between the timbre, feature and level factors. Hereafter, we present the two-way (Figure 8) and one-way (Figure 6 and 7) ANOVA tables.

Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Sound Origin	1275.8	2	637.878	3.02	0.0497
Properties	400	3	133.317	0.63	0.5948
Level	153.8	2	76.885	0.36	0.6948
Error	84385.2	400	210.963		
Total	86141	407			

Figure 6: One way ANOVA table for the Valence criterion (control group). F=3.02 , p<0.05 for the Sound Origin factor (timbre)

Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Sound Origin	15222.3	2	7611.17	23.91	0
Properties	778.8	3	259.61	0.82	0.4859
Level	1522.5	2	761.23	2.39	0.0929
Error	127352.1	400	318.38		
Total	144256.3	407			

Figure 7: One way ANOVA table for the Pleasantness criterion (control group). F=23.91, p<0.05 for the Sound Origin factor

Analysis of Variance

Source	Sum Sq.	d.f.	Mean Sq.	F	Prob>F
Sound Origin	11234.7	2	5617.37	18.04	0
Properties	636	3	211.99	0.68	0.5643
Level	2481	2	1240.48	3.98	0.0194
Sound Origin*Properties	4806.7	6	801.12	2.57	0.0187
Sound Origin*Level	1639.7	4	409.93	1.32	0.2632
Properties*Level	2276.9	6	379.49	1.22	0.2957
Error	119580.1	384	311.41		
Total	142358.9	407			

Figure 8: Two-way ANOVA table for the Arousal criterion (control group). Sound Origin ($F=18.04$, $p<0.05$), Sound Feature Level ($F=3.98$, $p<0.05$) and the Sound Origin *Sound Feature interaction factors ($F=2.52$, $p<0.05$).

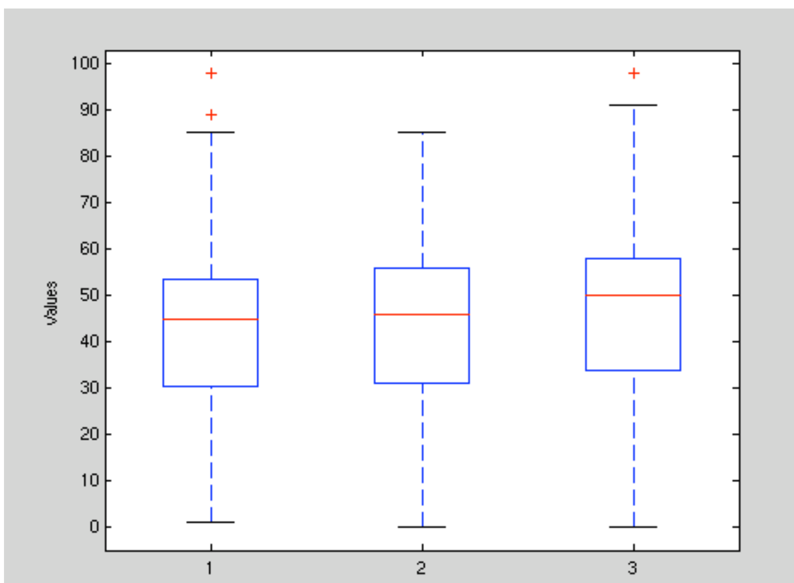

Figure 9: Boxplot of the Arousal ratings in function of the feature levels (1 is low, 2 is medium, 3 is high)

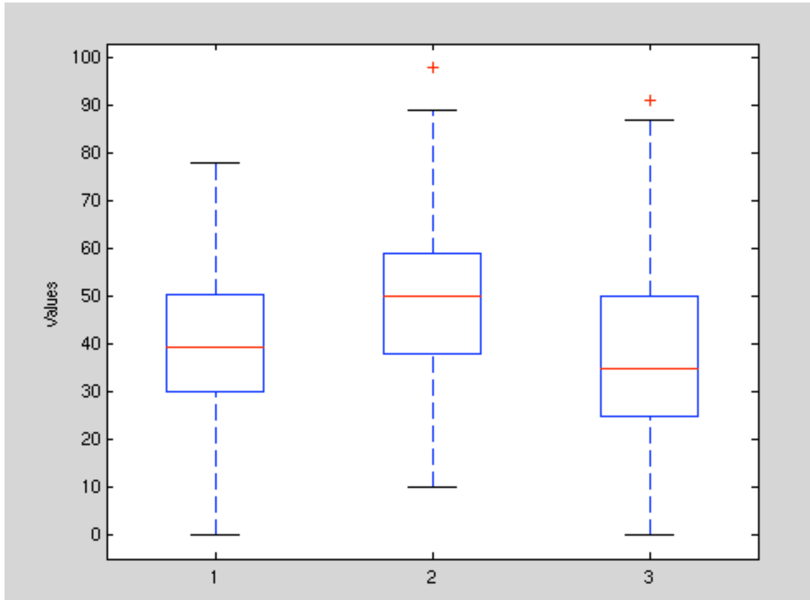

Figure 10: Boxplot of the Arousal ratings in function of the Timbre feature (1 is Synthetic, 2 is Voice, 3 is Water)

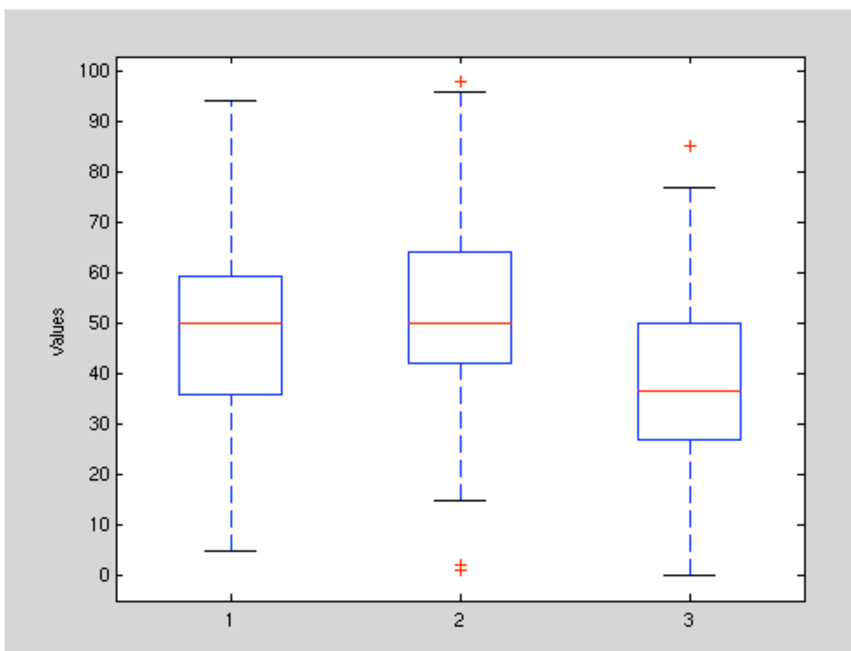

Figure 10: Boxplot of the Pleasantnes ratings in function of the Timbre feature (1 is Synthetic, 2 is Voice, 3 is Water)

Analysis of variance on the different sound categories showed that the timbre properties of sound were the most significant for the happy/sad distinction (Figure 6.) and that the higher the parameter level, the more the sound was reported to be stressful (Figure 8 and 9). We also observed that the pair fear/anger showed no significant correlation with the musical properties (Figure 5). The other answer pairs, however, did show statistically significant modulations that will need further analysis. The data also showed that the timbre origin of sounds (natural, synthetic, voice) has a direct impact on the reported emotional state of the patients (in Figure 6, 7 and 8, for the factor “timbre origin of sound”), e.g. synthetic sounds and voices were reported to be sad and relaxing (Figure 10) with a dislike for the latter category (Figure 11). However natural sounds were reported to be perceived as sad-relaxing while the patients liked it (Figure 10 and 11). The control group (N=8) and the patient group (N=65) showed statistically significant differences for the happy/sad ratings with respect to a number of musical properties. We observed that the patients had a tendency to be more extreme in their ratings than the controls.

Conclusion

In this paper we presented an experimental setup for studying the effect of sound parameters on dementia patients. Our preliminary results are promising and confirm the assumption that there are systematic relationships between reported subjective states and the refined sonic properties of the audio samples. These relationships significantly vary between AD patients and control subjects. Nevertheless, the data analysis is somewhat incomplete and we would like to investigate more sophisticated models (e.g non-parametric analysis) for evaluating the statistical significance of sonic features in the patient group. The final experiment will also take into account more control subjects tested in the exact same conditions as the patients. Some additional factors such as demographics of the patients, the time delay between each rating and the exact diagnosis are in the process of being collected and analyzed. Those preliminary results suggest that dementia patients have significantly different emotional responses to audio stimuli than healthy patients thus leading to possible application for automatic diagnosis. Moreover certain properties of sounds (such as water for example) have a relaxing and pleasant effect that could. help dementia patients decrease their anxiety and agitation.

One interesting finding is that the dementia patients had a tendency to give more sad ratings than control subjects. This could be associated with the fact that depression is one of the most frequent neuropsychiatric comorbidities of Alzheimer dementia (AD), affecting patients with rates from 0% to 87%. (Chinello, Grumelli , Perrone , Annoni, 2007). These depressive symptoms tend to occur early, are persistent, becoming increasingly common as dementia progresses (Amore , Tagariello , Laterza , Savoia, 2007). Depression decreases the quality of life of dementia sufferers, may reduce the duration of survival and would therefore appear to be important to treat. Music and music therapy may have an important role in helping to ameliorate this problem. Future research is certainly warranted.

Other clinical applications and implications of the results of this pilot study will be further discussed.

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