Social and Physiological Influences of Living with Seal Robots in an Elderly Care House for Two Months

Kazuyoshi Wada and Takanori Shibata

Abstract— **Robot therapy for elderly residents in a care house has been conducted since June 2005. Two therapeutic seal robots were introduced and activated for over 9 hours every day to interact with the residents. This paper presents a progress report of this experiment. In order to investigate the psychological and social effects of the robots, each subject was interviewed by using the free pile sort method, and their social interaction was analysed. In addition, their hormones in urine: 17 - Ketosteroid sulfate (17-KS-S) and 17 – hydroxycorticosteroids (17-OHCS) were obtained and analysed. The results showed that the robots encouraged them to communicate with each other and then strengthened their social ties over the two months. Furthermore, urine tests showed that the reactions of the subjects' vital organs to stress were improved after the introduction of the robots.**

Index Terms – Mental Commit Robot, Robot Therapy, Psychotherapy, Human-Robot Interaction, Elderly Care

I. Introduction

In recent years, robot therapy has attracted robotics researchers, psychologists, medical doctors, etc. [1]-[28]. They expect that interaction with animal-type robots will result in the mental effects of interacting with real animals. We have proposed robot therapy since 1996 [1]-[18]. We proposed a mental commit robot that provides mental value such as joy, happiness, relaxation, etc., to the subject through physical interaction. We developed a seal-type mental commit robot, named Paro, especially for robot therapy, and used it at pediatric hospitals and several facilities for the elderly, such as day service centers and health service facilities for the aged [7]-[11]. The results showed that interaction with Paro improved patients' and elderly people's moods, making them more active and communicative with each other and their caregivers. Results of urine tests revealed that interaction with Paro reduced stress among the elderly [11]. In addition, we investigated the long-term interaction between Paro and the elderly and found that the effects of interaction with Paro lasted for more a year [12]. Furthermore, the neuropsychological effects of Paro on patients with dementia were assessed by analyzing their EEGs [13]. The results showed that the activity of the patients' cortical neurons improved by interaction with Paro, especially in the case of those who liked Paro. Meanwhile, the studies conducted using questionnaires handed out at exhibitions held in six countries, namely, Japan, the U.K., Sweden, Italy, Korea, and Brunei, in order to investigate how people evaluate the robot. The results showed that the seal robot was widely accepted across cultures [15].

With regard to other research groups, Dautenhahn used mobile robots and Robins used robotic dolls for therapy with autistic children [19][20]. In addition, other animal-type robots (such as Furby, AIBO [21], NeCoRo, etc.) have been released by several companies. Robot therapy using these robots has also been attempted [22]-[26]. For example, For example, Yokoyama used AIBO in a pediatrics ward and observed the interaction between AIBO and the children [22]. He pointed out that when people met AIBO for the first time, they were interested in it for a brief period. However, relaxation effects such as those obtained from petting a real dog were never felt with AIBO. Kanamori et al. examined effects of AIBO on elderly in a nursing home by measuring hormone in saliva [25]. Tamura et al. also used AIBO for 5 minutes with patients exhibiting dementia and compared its effects with those of a toy dog [26]. In addition, some research groups used Paro for therapy of elderly in nursing homes and Alzheimer disease patient [27][28]. In the above related researches, people interacted with the robot during the certain period of session which was conducted by experimenter.

In this research, we have introduced Paro to a care house since June 2005. Two Paro were activated for over 9 hours every day in public areas of the care house and recorded their interaction by video cameras, in order to investigate how people interact with Paro under the freely accessible condition and its socio-psychological and physiological effects on the residents. So far we have reported the results of this experiment in the first month [16]-[18].

In this paper, we present the socio-psychological and physiological influences of robot therapy in this experiment by analyzing their social interaction and hormones in urine over *2 months*. Chapter II describes the seal robot that was used for robot therapy; chapter III describes the experimental methods used; Chapter IV describes the results; Chapter V discusses the current results of robot therapy and future work; and finally, chapter VI offers conclusions.

II. Seal Robot, Paro

The robot and its major functions are shown in Fig.1. Its appearance was designed using a baby harp seal as a model, and its surface was covered with pure white fur. A newly-developed plane tactile sensor was inserted

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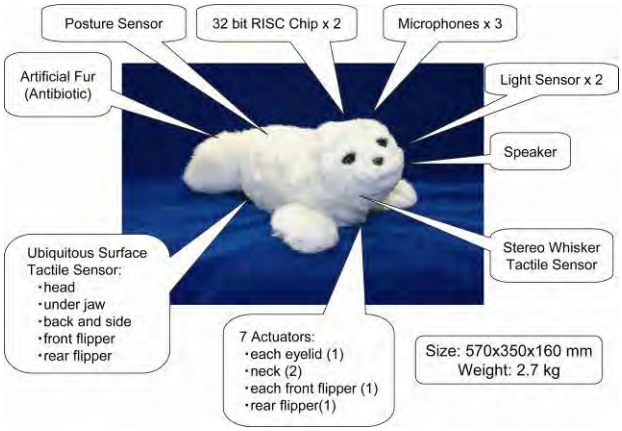


Fig.1 Paro, the Seal Robot

between the hard inner skeleton and the fur to create a soft, natural feel and to permit the measurement of human contact with the robot [14]. The robot is equipped with the four primary senses; sight (light sensor), audition (determination of sound source direction and speech recognition), balance and the above-stated tactile sense. Its moving parts are as follows: vertical and horizontal neck movements, front and rear paddle movements and independent movement of each eyelid, which is important for creating facial expressions. The robot operates by using the 3 elements of its internal states, sensory information from its sensors and its own diurnal rhythm (morning, daytime, and night) to carry out various activities during its interaction with people.

III. Robot Therapy in a Care House

A. Care House

The experiment has been conducted in the care house, "Mori-no-Ie" in Tsukuba city, Ibaraki prefecture, Japan. A care house is a type of communal housing in which basic daily care; is provided to residents, such as meals, bathing etc. Basically, the residents of care houses are aged over 60 years. They have physical difficulties in preparing their own meals and living alone. At the beginning of this experiment, 28 residents lived in the care house. We explained the purpose and procedure of this experiment to the residents and received their consent from 12 people, in line with the ethical committee of AIST. Regarding the video cameras, all the residents agreed their installation in a public area of the house.

B. Subjects

The number of subjects were 12, aged 67–89 (77.5 ± 7.3) years, including one male. Their mental cognitive states were assessed by MMSE [29]. Those with a score of above 23 were diagnosed as mentally healthy. The results revealed that their scores ranged from 15 to 29 (25.3 ± 3.9). Several subjects had symptom of forgetfulness; however all the subjects could take care themselves.

C. Methods of Interaction with Paro

The care house was situated on three floors. A dining room, hall, and office were on the 1st floor. Residential floors are located on the 2nd and 3rd floor. In the care house, the subjects spent most of time in their rooms alone and


Fig.2 Interaction with Seal Robot and Residents at Public area

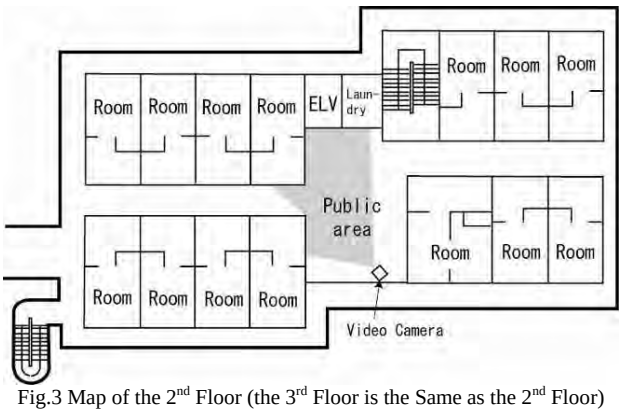


Fig.3 Map of the 2nd Floor (the 3rd Floor is the Same as the 2nd Floor)

visited the public area when they wished to communicate with other people. Spending time in another person's room was very rare. In addition, the public areas faced the lift foyer, an area used by all the residents; most of them offered greetings or indulged in small talk whenever they met other residents there. The public areas were the main place where the subjects communicated with each other freely. Therefore, spending time in these areas was important for their social interaction.

A Paro was introduced in the public area of the 2nd and 3rd floors, which were residential floors (Fig.2, 3). We assumed that Paro would be a topic of common interest for the subjects and would encourage them to communicate with each other. In particular, those who spent much time alone would leave their rooms and communicate with others. Consequently, they would spend more time in the area. Even though they visited the area alone, they would spend more time there playing with Paro; thus, the chance to communicate with other people would increase.

Caregivers activated Paro on the table in the public space of each floor at 8:30 and returned them to their office at 18:00. The residents could play with Paro whenever they wished during that time. Before introducing Paro, we explained that the latter is a robot and described its operation to the residents.

D. Methods of Evaluation

1) Interview

A free pile sort method was used to investigate social interaction among the residents [30]. It uses a deck of cards representing each of the residents in the care house and has the interviewee sort them and then talk through the

sort. Several blank cards are kept in hand. If the informant feels there are people missing, they are asked to fill in those people on the blank cards. They can sort these cards using their own classification system and during that time they basically build up a network. The stack of cards is shuffled randomly and returned to a respondent with the following instructions: "Here are a set of cards representing name of residents in this care house. I'd like you to freely sort them into piles. You can use as many or as few piles as you wish. Go!" An additional instruction: "For example, you can make the piles of your friends, having meal together, etc." was given to the people who couldn't understand how they should be sorted.

Regarding the relationship with Paro, people were interviewed along the lines of the following questions:

a) How is your daily life after introduction of the robots?

i) Do you speak to and touch the robot?
ii) When do you play with the robot?
iii) How often do you play with the robot?
iv) What do you call the robot?
v) Is the robot necessary/unnecessary in this house?
vi) What is the robot to you?

b) Are there any changes in your daily life?

At the beginning of interview, a respondent was asked the first question, "How is your daily life after introduction of the robots?" During his/her answering the question freely, interviewer asked him/her the rest of items interactively.

The subjects were interviewed, one by one, using these methods before and then one month after the introduction of Paro. Each interview took from approximately 30 minutes to 1 hour.

2) Urine Test

As a method of measuring stress, it is possible to evaluate physiologically by using urine tests that are a convenient a non-invasive inspection method for the elderly.

We investigated hormones in urine, 17-OHCS and 17-KS-S.

The 17-OHCS value rises during stress [31], 17-KS-S has high levels in healthy individuals and decreases with failing health or the progress of disease [32]. In addition, the 17-KS-S value exhibits sensitive changes with psychological and social factors, and relates greatly to a person's will, desire, and energy. The ratio 17-KS-S/17-OHCS, is a method of capturing the distortion of the living organisms brought about by stress or and gaining an inclusive understanding the living organisms reaction. It is reported that 17-KS-S/17-OHCS clearly indicates a low value (0.15 or less) under social and psychological stress and rises with release of the cause of the stress.

Subjects' urine was gathered in the early morning and was analyzed. Each value was corrected with the creatinine.

Urine tests were conducted on each subject, 3 to 5 days in the week before and every two weeks after the introduction of Paro. Each median value of hormones of before the introduction was used as the base condition for each subject. In the statistics analysis, Freedman's test was applied the data, and then Wilcoxon's sign rank sum test, was applied to the values for before and after the introduction. These statistical analyses were carried out using SPSS 12.0 for Windows.

IV. Results of Robot Therapy

A. Social Interactions among the Subjects and Paro

Before the introduction of Paro, the residents on the 2nd floor were relatively communicative compared with those on the 3rd floor. They discussed the weather, illnesses, gossiped about the other residents, etc. Moreover, 4 subjects played cards in the public area. On the contrary, most subjects on the 3rd floor only passed by the corridor. Normally, only 2 or 3 subjects spent a time in the public area to wait for their friends when they went for their meals.

We extracted their social interaction with the residents and with Paro from the interviews. Then, we classified them and defined the strength of social ties with other residents/Paro as follows:

1) Interaction with other residents

No tie:
a) Don't know the resident.
Weak tie:
b) Knowing his/her name. But greetings and small talk only.
Moderate ties:
c) Having meal at a same table.
d) Talking sometimes.
e) Living on the same floor.
f) Going to the dining room together.
g) Belonging to the same club activity.
Strong ties:
e) Meeting voluntarily and talking in public areas.
f) Playing cards together.
g) Visiting his/her room.
h) Going for a walk, shopping together.
i) Taking care of him/her. *ex.* Cooking a small dish and exchanging it.

2) Interaction with Paro

No tie:
a) Disregard
Weak ties:
b) Greeting when passing by.
c) Joining the interaction only when somebody was playing with it.
Moderate ties:
d) Talking to it when passing by.
e) Stroking and petting it.
f) Naming it.
g) Grooming it
Strong ties:
h) Voluntarily leaving own room to play with it.
i) Grumbling and sharing own feelings with it.
j) Inviting somebody to play with it together.

For example, a resident visited resident-B's room and his/her only interaction with Paro was a greeting; in such a case, the resident was defined as having a strong tie to resident-B and a weak tie to Paro. Before the introduction,

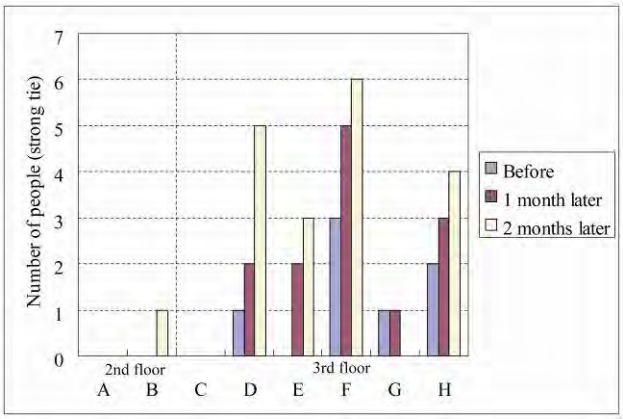


Fig.3 Change of number of people whom each subject had strong tie with among 8 subjects.

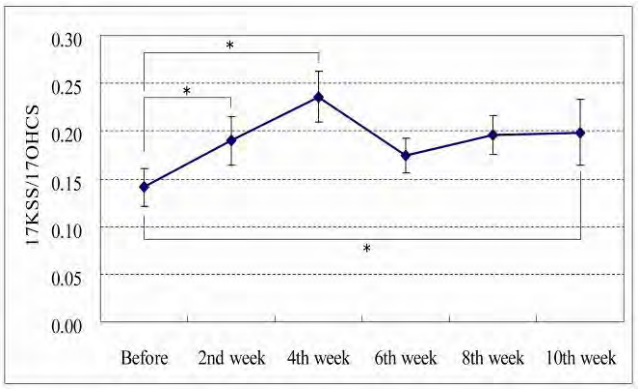
TABLE I. STRENGTH OF TIE WITH PARO

Subject	*1 month later*	*2 months later*
A	No tie	No tie
B	Moderate	Moderate
C	No tie	No tie
D	Strong	Strong
E	Moderate	Moderate
F	Strong	Strong
G	Strong	Moderate
H	Strong	Strong

all the residents knew each others name.

B. Relationship among the subjects

We investigated changes in the social interaction among the subjects. We excluded four subjects living on 2nd floor from the analyses because two subjects' health condition deteriorated and couldn't come to the public area or dining room; and one had a problem (which was unrelated Paro) with other residents after the introduction of Paro, and changed her social interaction. In addition, one showed reluctance to answer the pile sort. Fig.3 shows change of the number of people whom each subject had strong tie with among 8 subjects. The number of strong tie of subject B, D, E, F and H increased after introduction of Paro gradually. They commented that the atmosphere was brighter, the people became talkative, the chance to talk with other people increased and that abuse from the others had decreased. Especially, Subject E avoided other residents and usually stayed her room before introduction of Paro; after the introduction, whenever she found someone playing with Paro, she voluntarily joined the interaction and talked with other people. In addition, subject F had never visited 2nd floor before the introduction of Paro. However, after the introduction, she visited there to interact with Paro, and then she communicated with residents on the 2nd floor. As for the subject G, her strong tie decreased after two months. It seemed the influence that the friend moved to far table from her in the dining room. As for the subject A and C, they didn't have strong tie with the subjects. The subject A who was only male in the subjects was afraid of misconceptions and avoided being friend with women residents. The subject C disagreed with other subjects because she would like to talk about politics, but other subjects didn't much interest about that.



Wilcoxon's test *p < 0.05

Fig. 4 Change of 17KSS/17OHCS of Seven Subjects

C. Relationship with Paro

Table I shows change of the strength of tie with Paro. Subjects A and C had no ties with Paro. Subject A said "I'm too old to be relaxed by (playing with) such a thing." Comments from subject C were "I never interact with the robot, without a thought. *snip* I might be heartless." However, most subjects had moderate to strong ties with Paro. The subjects greeted the latter whenever they passed by and addressed it by the names that they had given it: Paro, Shi-shi maru, Mori-kun, Mori-chan, Shiro, and etc. Their strength of tie with Paro didn't change except the subject G. Her strength of tie changed from strong to moderate. In the first month, she commented that she talked her feelings to Paro sometimes, but she only greeted and groomed it after two months because she desired Paro to speak and answer to her talk.

D. Results of Urine test

We were able to obtain the data from 7 subjects. Fig. 4 shows the results of the ratio of 17-KSS-S/17-OHCS. The result of Freedman's test showed hormone ratio of 17-KS-S/17-OHCS changed significantly ($p < 0.01$). Especially, it was improved after the introduction of Paro. The ratio decreased after 4th week. It seemed that the change reflected the people accustomed themselves to Paro. However, it was still higher than those of before. We consider that interaction with Paro and the interaction through Paro with other people both physiologically improved the reaction of their vital organs, even though they accustomed to Paro over the two months interaction.

V. DISCUSSIONS

Before the introduction of Paro, the residents on the 3rd floor communicated very little with each other. The residents on the 2nd floor were relatively more communicative; however, they engaged in extensive backbiting about others. The concern was that exposure to such an environment would increase the risks of contracting sicknesses and cognitive decline.

The subjects who had strong or moderate tie with Paro increased gradually in the number of strong social tie with other subjects over the two months. In addition, urine tests showed that the reactions of their vital organs to stress were improved. The current results show that Paro has high potential to decrease those risks.

In this experiment, the subject G complained about speech ability of Paro and then changed her social interaction with Paro. However, if robot could speak something, people would expect unconsciously the robot has same speech ability as humans. Unfortunately, there still is no such technology; therefore people would be disappointed in the robot. There is a tradeoff between the desired function and technology. The investigation of relationship between the functions of robot and its effects is future work.

VI. CONCLUSIONS

We have used seal robots (Paro) for elderly residents in a care house since June 2005. The residents freely interacted with Paro for over 9 hours daily. The current results show that Paro encouraged them to communicate with each other and brought about psychological improvements in them over *2 months*. Paro became playing a stronger role as social mediator among the subjects. Physiologically, urine tests showed that the reactions of their vital organs to stress were improved by the introduction of Paro. Especially, the peak of the physiological effects was shown in the first month. In this research, video cameras were installed in order to more objectively investigate changes in their social interaction with each other and Paro. The details will be described in the future. We will report more long-term influences on the residents of the care house in the future.

REFERENCES

[1] T. Shibata, et al., Emotional Robot for Intelligent System - Artificial Emotional Creature Project, Proc. 5th IEEE Int'l Workshop on ROMAN, pp. 466-471, 1996.

[2] T. Shibata and R. Irie, Artificial Emotional Creature for Human-Robot Interaction - A New Direction for Intelligent System, Proc. the IEEE/ASME Int. Conf. AIM'97 paper # 47, 1997.

[3] T. Shibata, et al., Artificial Emotional Creature for Human-Machine Interaction, Proc. the IEEE Int. Conf. SMC, pp. 2269-2274, 1997.

[4] T. Shibata, et al. Emergence of Emotional Behavior through Physical Interaction between Human and Robot, Proc. the IEEE ICRA, 1999.

[5] T. Shibata, et al. Subjective Interpretation of Emotional Behavior through Physical Interaction between Human and Robot, Proc. SMC, pp. 1024-1029, 1999.

[6] T. Shibata, K. Tanie, Influence of A-Priori Knowledge in Subjective Interpretation and Evaluation by Short-Term Interaction with Mental Commit Robot, Proc. IEEE Int. Conf. IROS, 2000.

[7] T. Shibata, et al., Mental Commit Robot and its Application to Therapy of Children, Proc. the IEEE/ASME Int. Conf. AIM 2001 paper #182

[8] T. Shibata, et al. Robot Assisted Activity for Senior People at Day Service Center, Proc. Int. Conf. ITM, pp.71-76, 2001.

[9] K. Wada, et al., Effects of Robot Assisted Activity for Elderly People and Nurses at a Day Service Center, Proc. of the IEEE, Vol.92, No.11, pp.1780-1788, 2004.

[10] K. Wada, et al. Analysis of Factors that Bring Mental Effects to Elderly People in Robot Assisted Activity, Proc. IEEE Int. Conf. IROS, 2002.

[11] T. Saito, et al. Examination of Change of Stress Reaction by Urinary Tests of Elderly before and after Introduction of Mental Commit Robot to an Elderly Institution, Proc. Int. Symp. AROB Vol.1 pp.316-319, 2002.

[12] K. Wada, et al. Psychological and Social Effects of One Year Robot Assisted Activity on Elderly People at a Health Service Facility for the Aged, Proc. IEEE ICRA, pp.2796-2801 2005

[13] K. Wada, et al. Effects of Robot Therapy for Demented Patients Evaluated by EEG, Proc. the IEEE/RSJ Int. Conf. IROS, pp.2205-2210, 2005.

[14] T. Shibata, Ubiquitous Surface Tactile Sensor, 2004 1st IEEE TExCRA Proc. pp. 5, 6, 2004.

[15] T. Shibata : An Overview of Human Interactive Robots for Psychological Enrichment, Proc. of the IEEE, Vol.92, No.11, pp.1749-1758, 2004.

[16] K. Wada & T. Shibata, Robot Therapy in a Care House - Its Sociopsychological and Physiological Effects on the Residents, Proc. IEEE ICRA, pp.3966-3971, 2006.

[17] K. Wada & T. Shibata, Robot Therapy in a Care House - Results of Case Studies -, Proc. IEEE Int. Workshop ROMAN, pp.581-586, 2006.

[18] K. Wada & T. Shibata, Living with Seal Robots in a Care House - Evaluations of Social and Physiological Influences -, Proc. the IEEE/RSJ Int. Conf. IROS pp.4940-4945, 2006

[19] I. Werry and K. Dautenhahn, Applying Mobile Robot Technology to the Rehabilitation of Autistic Children, Proc. of 7th Int. Symp. Intelligent Robotic Systems, pp.265-272, 1999.

[20] B. Robins, et al. Robotic Assistants in Therapy and Education of Children with Autism: Can a Small Humanoid Robot Help Encourage Social Interaction Skills? Journal of Universal Access in the Information Society, Vol.4, No.2, 2005.

[21] M. Fujita and H. Kitano, An Development of an Autonomous Quadruped Robot for Robot Entertainment, Autonomous Robots, Vol.5, pp.7-18, 1998.

[22] A. Yokoyama, The Possibility of the Psychiatric Treatment with a Robot as an Intervention -From the Viewpoint of Animal Therapy-, Proc. Joint 1st Int. Conf. SCIS and ISIS, paper #23Q1-1, 2002.

[23] E. Libin, and A. Libin, Robotherapy: Definition, Assessment, and Case Study, Proc. the 8th Int. Conf. Virtual Systems and Multimedia, pp.906-915, 2002.

[24] E. Ohkubo, et al. Studies on Necessary Condition of Companion Robot in the RAA Application, Proc. 2003 IEEE Int. Symp. CIRA, pp.101-106, 2003.

[25] M. Kanamori, et al. [Maintenance and Improvement of Quality of Life Among Elderly Patients Using a Pet-type Robot], Nippon Ronen Igakkai Zasshi. Vol.39, No.2, pp.214-218, 2002. (Japanese)

[26] T. Tamura, et al. Is an Entertainment Robot Useful in the Care of Elderly People with Severe Dementia? Journal of Gerontology: Medical Sciences, Vol.59A, No.1, pp.83-85, 2004.

[27] C. Kidd, et al. A Social Robot to Encourage Social Interaction among the Elderly, Proc. IEEE ICRA, pp.3972-3976, 2006.

[28] P. Marti, et al. Socially Assistive Robotics in the Treatment of Behavioral and Psychological Symptoms of Dementia, Proc. BioRob 2006.

[29] M. F. Folstein, et al. Mini-Mental State: a Practical Method for Grading the Cognitive State of Patients for the Clinician, Journal of Psychiatric Research, Vol.12, pp.189-98, 1975.

[30] S. Weller & A. Romney, Systematic Data Collection. Qualitative Research Methods Series 10. California: Sage Publications Inc. 1988.

[31] Selye H.: Stress and aging, Journal of American Geriatric Society, Vol.18, pp. 669-676, 1970.

[32] O. Nishikaze, et al., Distortion of Adaptation (Wear & Tear and Repair & Recovery)-Urine 17- KS-Sulfates and Psychosocial Atressin Humans-Job Stress Res, Vol.3, pp. 55-64. 1995.