We are IntechOpen,
the world's leading publisher of
Open Access books
Built by scientists, for scientists

6,900
Open access books available

185,000
International authors and editors

200M
Downloads

Our authors are among the

154
Countries delivered to

TOP 1%
most cited scientists

12.2%
Contributors from top 500 universities

CLARIVATE ANALYTICS
BOOK CITATION INDEX
INDEXED

WEB OF SCIENCE™

Selection of our books indexed in the Book Citation Index
in Web of Science™ Core Collection (BKCI)

Interested in publishing with us?
Contact book.department@intechopen.com

Numbers displayed above are based on latest data collected.
For more information visit www.intechopen.com

Communication assistive method using sympathetic skin response

Fumihiko Masuda and Chikamune Wada

Graduate School of Life Science and Systems Engineering, Kyushu Institute of Technology

Japan

1. Introduction

Persons with seriously disabled speech organs and motor function have difficulty in speaking and communicating through hand gestures. Communication aids have been developed based on AAC (Augmentative and Alternative Communication) concept, and are being used to assist in the transmission of the user's intention. However, the disabled person must have residual motor function to operate most of these aids. If the disabled person has few motor functions, such communication aids can hardly be used; also, if the disabled person has a progressive disease, it is necessary to constantly adjust the communication aid to the level of residual motor function. To overcome this problem, a device that does not depend on residual motor function must be developed.

Recently, a study on BCI (Brain Computer Interface) was carried out, which used electroencephalograms as a communication aid that does not depend on residual motor function (Friedrich et al., 2009). The electroencephalogram switch MCTOS (Technos Japan Co., Ltd.) has already been put to practical use. However, MCTOS must recall exciting and frustrating when the user switches it on. Therefore, MCTOS is hard to operate and to have the feeling that it was switched on purposefully (Nakabayashi et al., 2003).

A possible solution to this problem is to use SSR (Sympathetic Skin Response), which can be measured non-invasively and is independent of residual motor function. SSR, which is a biomedical signal that reflects the activity of the sympathetic nervous system, is affected by both cognitive thinking and decision-making (Ito et al., 1996). We hypothesized that the SSR response could be used as a switch in a communication aid which can convey the user's wish to see a character or a picture displayed on a personal computer. In addition, the advantage of SSR is that measurements can be made easily, unlike with the electroencephalogram, and it is not necessary to think about something else (mental arithmetic, exciting and frustrating) irrelevant to the operation of switching on the communication aid; thus, intuitive operation is possible (Fig.1). It has been reported that disabled persons with SCI (Spinal Cord Injury) and ALS (Amyotrophic Lateral Sclerosis) show amplitude reduction and extension of the SSR latency period. In addition, the absence of SSR response has been confirmed in several patients. However, there are few reports on completely absent SSR (Masur et al., 1995, Oey et al., 2002, Nicotra et al., 2002). On the other

hand, differences in SSR response by measurement site have been found and investigated (Masur et al., 1995, Nicotra et al., 2002).
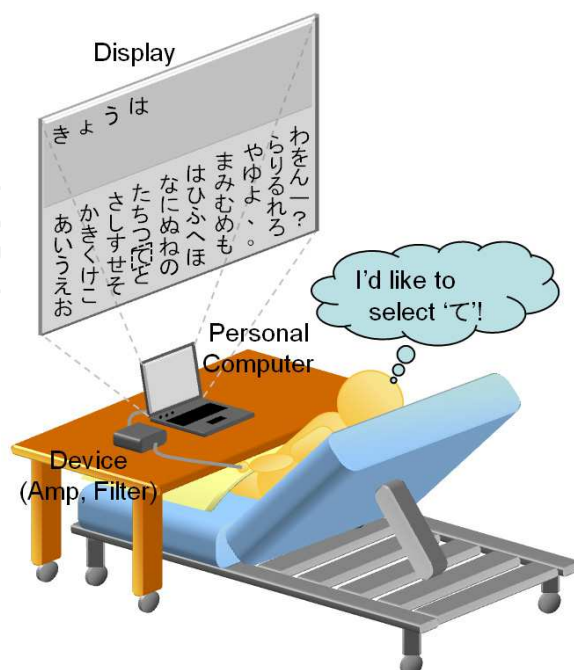

Fig. 1. Image of communication assistive method with sympathetic skin response

In our previous study (Masuda & Wada, 2005), we performed an experiment in which a character was selected on a display by mental intention based on the subject's SSR; we demonstrated the possibility of using SSR as a substitute for the on/off switching of the communication aid. However, this is not to say that SSR was invariably evoked precisely when the user intended; the rate at which the user was able to select a character definitely was 50 to 80%. Tsukahara and Aoki brought up that the SSR appearance ratio was low (Tsukahara & Aoki, 2002).

As one of the causes that SSR was evoked irrespective of the user intention, we thought the psychological change of the user. We hypothesized that the psychological change of the user was evoked the endogenous and the exogenous stimulus. The endogenous stimulus evoke the user's other thought that irrespective of the original task. At the same time, the exogenous stimulus is caused by the environmental sounds and the display method etc. The environmental sounds is stimuli from auditory sense, the display method is stimuli from visual sense. There are sound (Hilz et al., 1999) and visual (Yamashiro et al., 2004) stimuli as factor which SSR evokes. It was reported that these stimuli evoke SSR because of the psychological change (Damasio et al., 1990, Khalfa et al., 2002). It is difficult to control the endogenous stimulus. However, it is possible to control the some exogenous. Therefore, we thought that if the influence of the exogenous stimuli is clear, it is possible to clarify whether a condition exists under which the SSR appears readily or not readily.

In previous our study, we explained the influence of sound stimuli on SSR (Masuda & Wada, 2007). In this study, we first indicated the possibility of using SSR as a substitute for the on/off switching of the communication aid in ALS based on our previous study (Masuda & Wada, 2005). Additionally, we had an interest in the visual stimuli, investigated the optimal visual scanning speed (kana display time) in order to development of communication

assistive device using SSR. We constructed a communication aid based on SSR experimentally using a visual scanning system. However, there is a time lag between the imagining of the kana and observable skin potential change in SSR. This time lag (latency) is approximately 1.3 seconds when the SSR was measured on the hand (Yokota et al., 1991). Thus, we expected the kana selection accuracy with SSR to show a change if the optimal visual scanning speed (kana display time) was used.

2. Sympathetic skin response

2.1 Fundamentals

The emotional state, cognitive activity, and information processing ability of an individual can be evaluated by mental sweating using electricity to measure mental activity through the galvanic skin response (GSR) (Fujisawa et al., 1998). The GSR was first reported in 1888 by Féré, and has been widely used in fields such as psychology (Féré, 1888).

Sympathetic skin response (SSR), proposed by Shahani et al. in 1984, is a test performed to measure a change in the electrical potential by applying a spiritual or emotional impulse, which can be measured in the palm or sole (Shahani et al., 1984). Because the detection potentials of SSR widely range from several millivolts to several hundred volts, we can obtain by the electroencephalograph or electromyograph more easily than the GSR. SSR has recently become more widely used as an objective evaluation test for assessing autonomous nervous system functions (Mitani & Ishiyama, 2008, Uozumi & Matsunaga, 2005).

2.2 Characteristics

SSR generation source is thought that 2 of an electric potential change by the sweat gland activity (the depolarization of the secreting cell, the fullness of duct in sweat gland, Na^+ and Cl^- reabsorption etc.) and the epidermal membrane potential change were complicatedly composed as for the generation source of electric potential change in SSR (Uozumi & Matsunaga, 2005).

The mechanism of development in SSR is not completely found out. However, the reflex path is similar the reflex path of GSR (Watahiki, 1987).

It is often used that the electric stimuli, magnetic stimuli, inspiratory gasp and sound stimuli for stimulation to evoke SSR. Generally, the wave pattern of an SSR consists of two or three phases: in most patterns, the skin potential varies from negative to positive (Fig. 2).
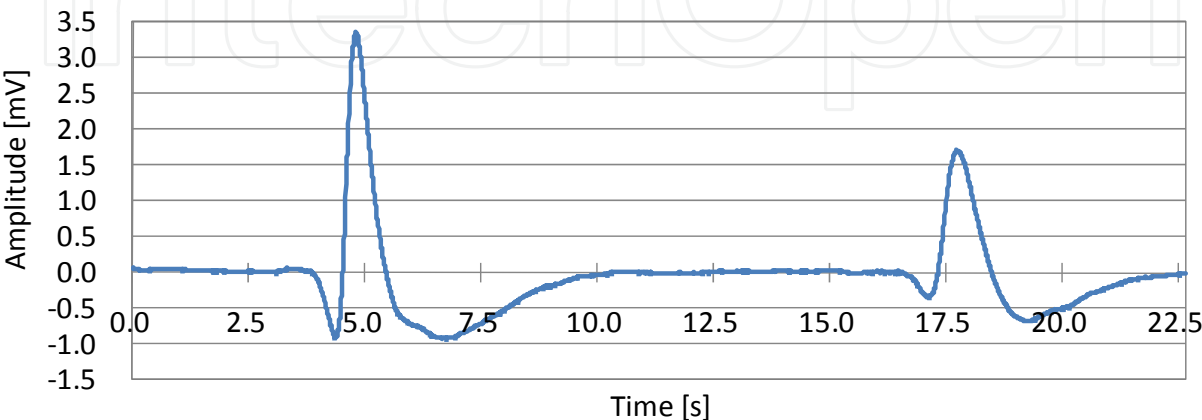

Fig. 2. A typical SSR pattern

However, some potential changes are seen only in the positive phase, while some are seen only in the negative phase and some in other changes including positive–negative patterns (Uozumi & Matsunaga, 2005). The changes in amplitude differ for every trial and subject. In addition, many studies have reported latency (a time lag between imagining the kana and observable skin potential changes) as 1.27 to 1.51 s as the mean for the palm (Uozumi & Matsunaga, 2005). Latency is less apt to change with changes in the type and strength of the stimulus.

Tables 1 and 2 show typical data for the latency and amplitude of an SSR (Iwase & Mano, 1996).

Author	Palmar Response	
	Latency (s)	Amplitude (mV)
Baba (Baba et al., 1988)	1.34 ± 0.11	1.79 ± 0.83
Elie (Elie & Guiheneuc, 1990)	1.49 ± 0.07	2.90 ± 1.70
Knezevic (Knezevic & Bajada, 1985)	1.52 ± 0.13	0.48 ± 0.10
Schondolf (Shondorf & Gendron, 1990)	1.48 ± 0.24	2.54 ± 1.27
Shahani (Shahani et al., 1984)	1.39 ± 0.07	0.81 ± 0.32
Soliven (Soliven et al., 1987)	1.31 ± 0.18	0.79 ± 0.35
Valls-Sole (Valls-Sole et al., 1991)	1.53 ± 0.24	0.47 ± 0.18
Van den Bergh (Van den Bergh & Kelly, 1986)	1.40 ± 0.10	0.18 ± 0.09
Yokota (Yokota et al., 1991)	1.34 ± 0.10	5.53 ± 3.24

Table 1. The characteristic latency and amplitude of palmar SSRs (Iwase & Mano, 1996)

Author	Plantar Response	
	Latency (s)	Amplitude (mV)
Elie (Elie & Guiheneuc, 1990)	2.70 ± 0.12	1.40 ± 0.80
Knezevic (Knezevic & Bajada, 1985)	2.07 ± 0.16	0.10 ± 0.04
Schondolf (Shondorf & Gendron, 1990)	2.04 ± 0.31	2.17 ± 1.62
Shahani (Shahani et al., 1984)	1.88 ± 0.11	0.64 ± 0.28
Soliven (Soliven et al., 1987)	1.93 ± 0.17	0.39 ± 0.23
Valls-Sole (Valls-Sole et al., 1991)	2.10 ± 0.25	0.16 ± 0.09
Van den Bergh (Van den Bergh & Kelly, 1986)	1.80 ± 0.10	0.08 ± 0.05
Yokota (Yokota et al., 1991)	1.84 ± 0.28	1.64 ± 1.08

Table 2. The characteristic latency and amplitude of plantar SSRs (Iwase & Mano, 1996)

2.3 Previous studies

From the many published reports on the SSR of severely disabled individuals, we hypothesized that SSR could be used as a switch in a communication-assistive device for individuals with severely disabled speech organs and motor functions.

Thus far, the autonomic nervous symptoms observed in ALS. However, Masur et al. systematically investigated the autonomic functions in ALS patients by SSR (Masur et al., 1995); the absence of SSR was seen in 4 of 15 patients in one or in all measurement sites. Assessing the involvement of the autonomic nervous system other than the cardiovascular system in ALS, Oey et al. found that palmar SSR was present in all ALS patients, whereas plantar SSR could not be measured in 3 of 15 patients (Oey et al., 2002). Dettmers et al.

assessed the involvement of the autonomic nervous system in 25 ALS patients; SSR was absent in 40% patients and the latency of SSR was prolonged (Dettmers et al., 1993).

When the sympathetic sudomotor function was evaluated in disabled individuals with SCI, the presence or absence of SSR was observed in chronic SCI patients (Nicotra et al., 2002). In patients with SCI, Kumru et al. aimed to characterize the expected dysfunction of the circuits responsible for SSR; SSR to any stimulus were absent in hand and foot (Kumru et al., 2009). Wang et al. reported that abnormal SSR was seen in 9 of 62 patients with Parkinson disease (Wang et al., 1993).

Although these studies investigated the absence of SSR, prolonged SSR latency, and abnormal SSR amplitude, there are few reports on completely absent SSR. Thus, we studied the effective use of SSR by including ALS patients.

3. Character selection with SSR in ALS patients

3.1 Purpose of the experiment

In our previous study (Masuda & Wada, 2005), the effectiveness of determining SSR by including healthy individuals led us to investigate the effectiveness of determining SSR as an input switch for ALS patients.

3.2 Methods

The subjects comprised four healthy males (mean age 23.0 ± 1.4 years) without any abnormality and five ALS patients (mean age 63.6 ± 6.5 years, mean disease duration 124.8 ± 57.9 months, four males and one female) (Table 3). They understood the nature of the experiment and provided prior consent for inclusion in the study.

Patient No.	Sex	Age Years	Duration of the disease Months
1	Male	65	192
2	Male	67	168
3	Male	70	72
4	Male	63	132
5	Female	53	60
Mean value		63.6	124.8
Standard deviation		6.5	57.9

Table 3. The characteristics of the patients with ALS.

Figures 3 and 4 depict the experimental setup. The experiment was performed in a quiet room in which the temperature was maintained between 25–28°C. A laptop computer was placed in front of each subject. The computer was used to show kana (Japanese written characters) for character selection.

Three Ag/AgCl electrodes were used to detect skin potential activity. The detection electrode was placed on the palm, and the reference and earth electrodes were placed on the back of the hand. Biomedical amplifier (LEG-1000, Nihon Kohden) was used for recording at a sampling frequency of 200 Hz.

The corresponding kana were displayed sequentially on the screen. The subject was asked to imagine selecting a predetermined kana (target kana) as it was displayed at an interval of 3.0 s. The other characters were assumed to be nontarget kana. The SSR signals were detected with templates from previously recorded skin potential activity.

The kana selection accuracy was calculated by dividing the total number of times the SSR signals were detected by the total number of times the kana were displayed. The kana selection accuracy is then calculated for the target and nontarget kana.
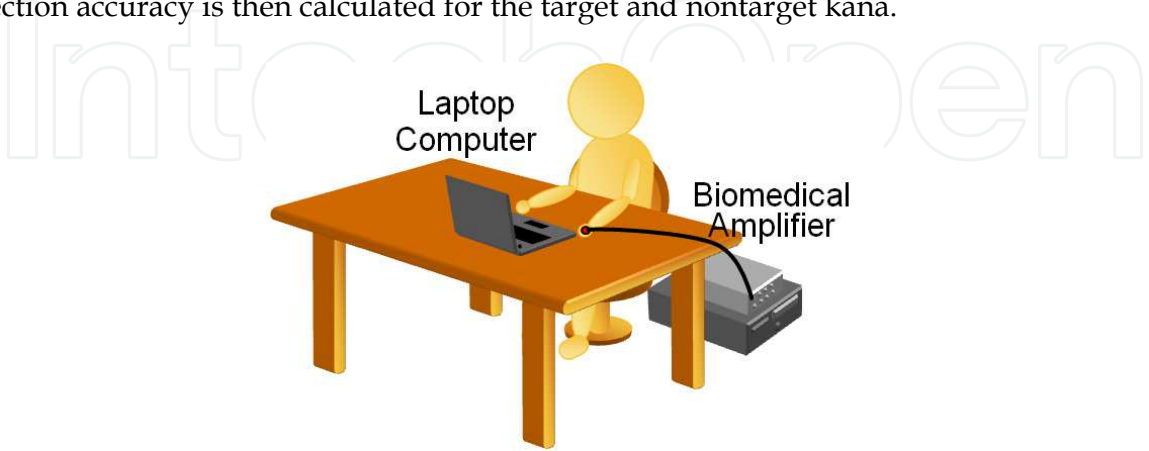
Fig. 3. Experimental setup involving a healthy subject
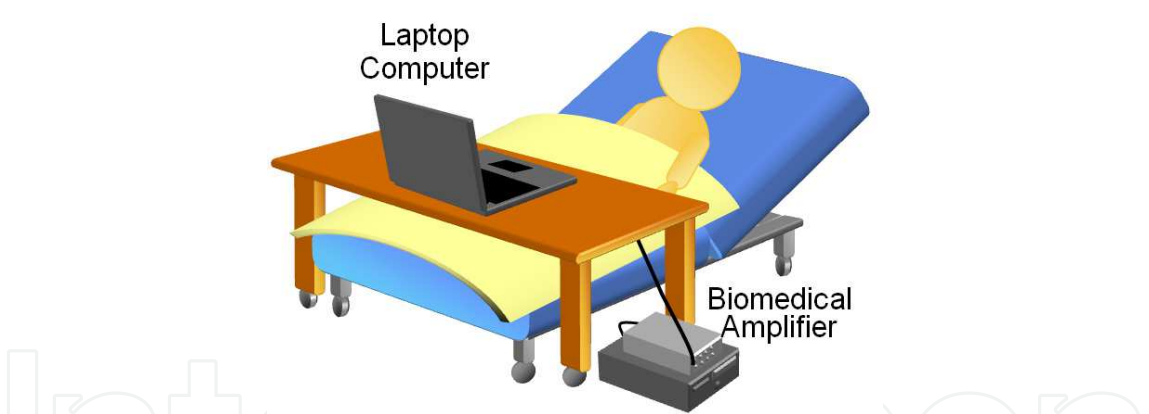
Fig. 4. Experimental setup for an ALS patient

3.3 Results and discussion

For the target and nontarget kana, the kana selection accuracy by SSR is shown in Fig. 5, amplitude of SSR in Fig. 6, and latency of SSR in Fig. 7. The left bar indicates the healthy group and the right bar indicates the ALS group. The graph shows average values ± standard deviation [%].

In Fig. 5, an SSR appeared in all subjects for the nontarget kana. However, it did not appear in two subjects with ALS for the target kana. We assumed that this absent SSR is not a clinical sign for ALS, because SSR appeared in all ALS subjects for the nontarget kana. Regarding kana selection accuracy, no difference was confirmed between the healthy and ALS groups.
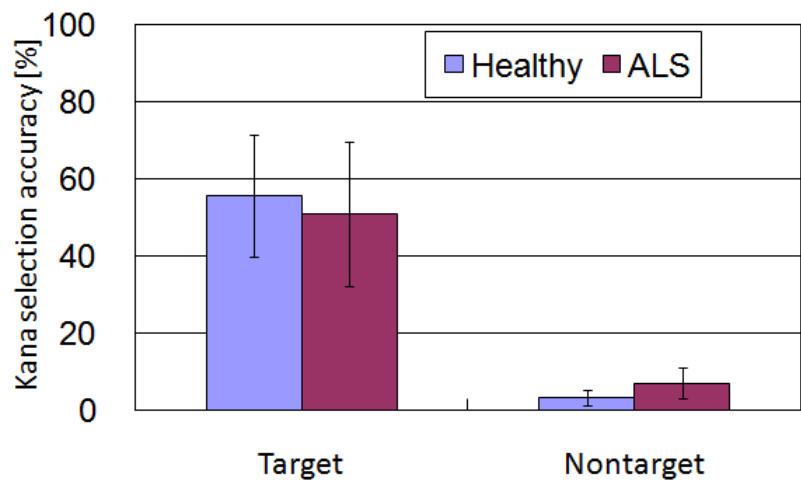
Fig. 5. Kana selection accuracy in healthy individuals and those with ALS
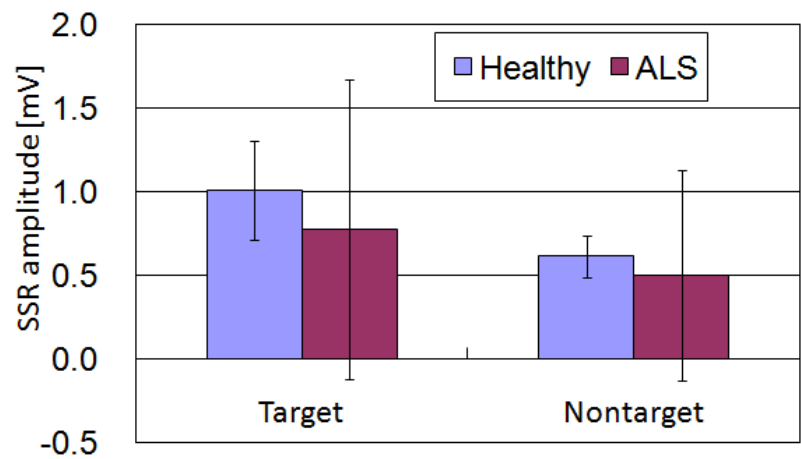

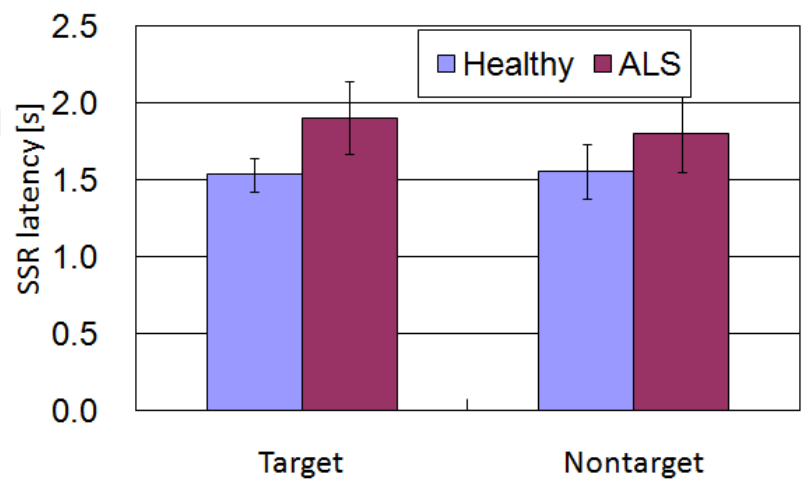Fig. 6. The amplitude in healthy individuals and those with ALS

Fig. 7. SSR latency in healthy individuals and those with ALS

Regarding the amplitude, a large SSR evoked in one ALS patient resulted in a large standard deviation in the ALS group. The amplitude in the ALS group was slightly smaller than in the healthy group. The latency in the ALS group was slightly longer than in the healthy group. The decrease in the amplitude and extension of latency are in agreement with those reported in a previous study (Dettmers et al., 1993, Masur et al., 1995, Oey et al., 2002). However, SSR was not completely absent in ALS patients. Therefore, we hypothesized that even severely disabled individuals such as those with ALS might use a communication-assistive device based on SSR.

4. Visual scanning speed

4.1 Purpose of the experiment

We constructed an experimental communication device based on SSR using a visual scanning system. Because there is latency in SSR, we must compensate for latency in the design for the visual scanning speed of the system because there is a possibility that the user cannot discern how to properly choose a kana. In addition, we believed that the selection accuracy of a kana with SSR might change with a change in the visual scanning speed. Therefore, we also examined the effect of the visual scanning speed on SSR.

4.2 Methods

The subjects were healthy males without any abnormality. He understood the nature of the experiment and provided their consent prior to their inclusion in the study.

Fig. 8 depicts the experimental setup. It was similar to that shown in Fig. 3. The experiment was performed in a quiet room in which the temperature was maintained between 24-26°C. A display was placed in front of the subject at a distance of 50 cm from him.
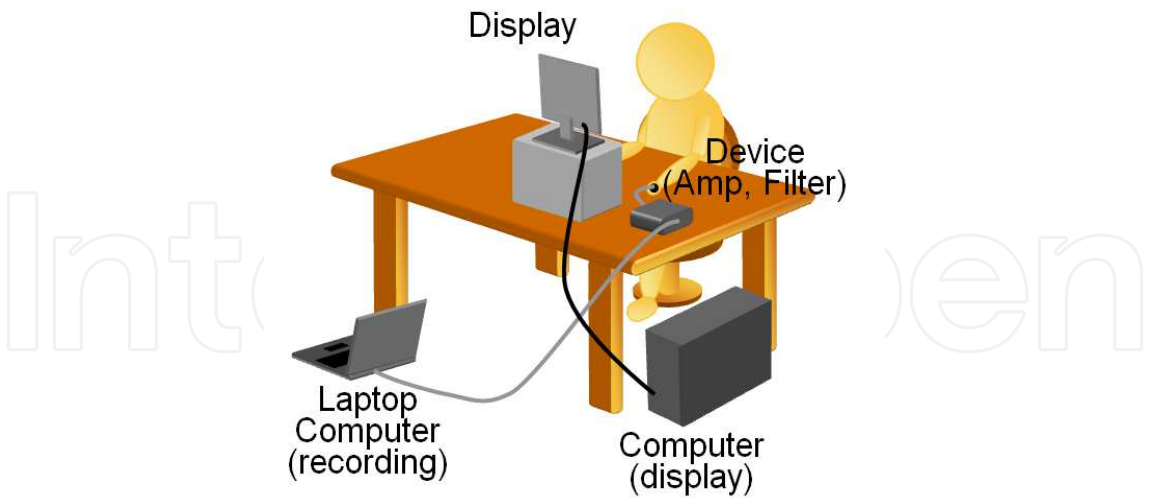

Fig. 8. Experimental setup

In Fig. 3, LEG-100 was used to measure the skin potential activity. In this experiment, the skin potential activity was measured by a prototype communication-assistive device that detects SSR. Fig. 9 shows a block diagram of a communication-assistive device using SSR. The device comprised an amplifier, filter, and A/D converter. Recordings were amplified

1000 times, filtered using a band pass filter between 0.05 and 30 Hz, converted at a sampling rate of 200 Hz using the A/D converter, and recorded using a computer. Recorded data were analyzed using self-produced software in real-time; the execution screen of software is shown in Fig. 10.
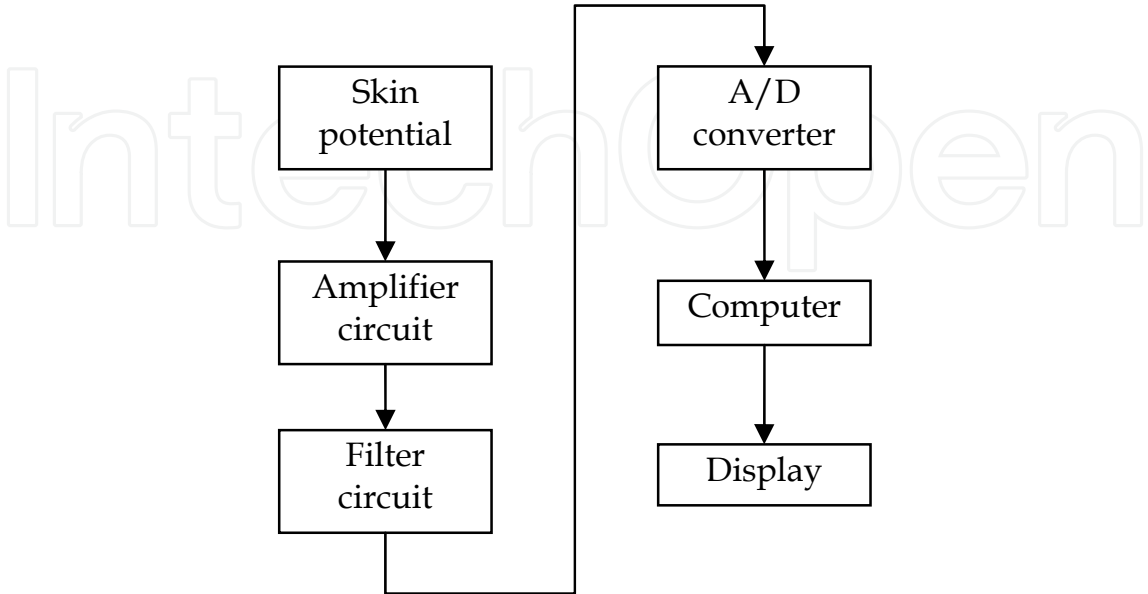
Fig. 9. Block diagram of a communication-assistive device using SSR

Fig. 10. The execution screen of the software

The threshold of the SSR amplitude was determined to assess whether or not an SSR appeared due to a change in skin potential. The threshold of each subject was determined based on the amplitude of SSR evoked by an inspiratory gasp before the experiment; any change in the skin potential with two or three phases beyond this threshold was considered an SSR. Usually, SSR latency is defined as the time between the stimulus and the change in

skin potential. However, in this experiment, it was difficult to precisely identify the moment when the subjects began to imagine selecting the kana. Therefore, we defined SSR latency as the time between the time when the kana was displayed on the screen and the change in skin potential. The kana selection accuracy was calculated by dividing the total number of times SSR signals were detected by the total number of times kana were displayed. The kana selection accuracies were calculated for the target and nontarget kana.

Three Ag/AgCl electrodes were used to detect skin potential activity. The detection electrode was placed on the palm of one hand, and the reference and earth electrodes were placed on the back of the same hand.

During the experiment, the subject was asked to imagine selecting a predetermined kana (the target kana) as soon as it was displayed. Although the Japanese syllabary is commonly used with the help of a visual scanning system, in order to investigate the relationship between the display time for the kana in this experiment, the latency period and the appearance ratio of SSR, five characters ('あ', 'い', 'う', 'え' and 'お') were individually displayed 10 times each. The target kana was 'う'. The display times were 2.5, 5.0, 7.5, and 10.0 s. This set of display times was based on the results of our past experiments, and 2.5 s was set as the standard display time. These four display times were randomly deployed and the experiment was repeated five times.

4.3 Results

Figure 11 shows the relationship between kana selection accuracy and display time. The graph shows average values ± standard error [%]. The purposeful selection accuracy, when an SSR appeared for the target kana, was 52.0 ± 5.8% (display time: 2.5 s), 76.0 ± 4.0% (display time: 5.0 s), 80.0 ± 6.3% (display time: 7.5 s), and 80.0 ± 5.5% (display time: 10.0 s). The accidental selection accuracy, i.e., when an SSR appeared for the nontarget kana, was 2.0 ± 0.9% (display time: 2.5 s), 14.0 ± 3.5% (display time: 5.0 s), 20.5 ± 3.5% (display time: 7.5 s), and 21.5 ± 3.8% (display time: 10.0 s).
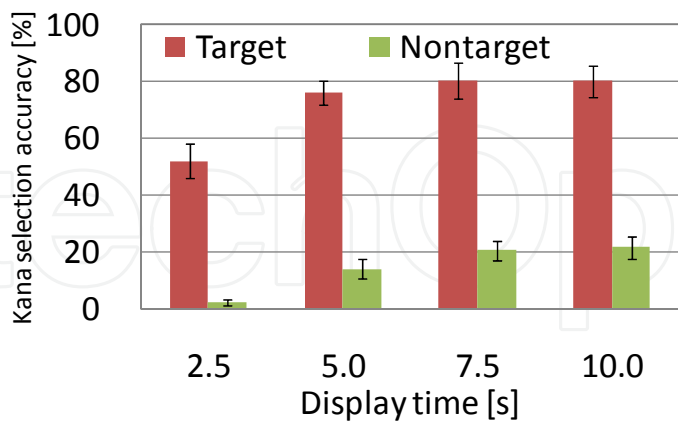

Fig. 11. Kana selection accuracy

One-way ANOVA analysis showed that the display time was significant for both target and nontarget kana (target kana: $F = 0.006$, $p < 0.01$; nontarget kana: $F = 0.001$, $p < 0.01$). The results of multiple comparisons using the Tukey test revealed that the display time of 2.5 s was significantly lower than that of the other display times for both the target and nontarget kana.

Figure 12 shows the relationship between SSR latency and display time. The SSR latency values in Fig. 12 are averages ± standard error [s] when an SSR appeared for the target kana. SSR was also detected when nontarget kana were displayed: this SSR was a response not intended by the subjects. It was difficult to precisely identify the moment of stimulus onset; therefore, SSR latency was analyzed only for the target kana.

SSR latency was 2.04 ± 0.04 s (display time: 2.5 s), 2.60 ± 0.10 s (display time: 5.0 s), 3.79 ± 0.18 s (display time: 7.5 s), and 4.21 ± 0.37 s (display time: 10.0 s). The graph shows that SSR latency increases with the kana display time. In addition, the standard error increases with display time.
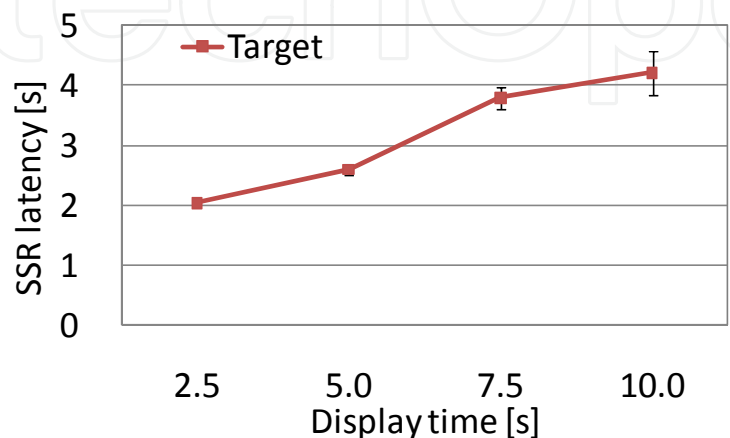

Fig. 12. SSR latency

4.4 Discussion

Figure 11 indicates that the kana selection accuracy for the display time of 2.5 s was significantly lower than that for the other display times. In other words, the selection accuracy was not significantly different for the display times of 5.0, 7.5, and 10.0 s. For the target kana, the selection accuracy was approximately 50% for the display time of 2.5 s. We assumed that the selection accuracy decreased in this case compared with the other display times because the display time was short. SSR latency was approximately 2.0 s for the display time of 2.5 s (Fig. 12), indicating that it took 2.0 s to recognize the displayed kana and hence we can acknowledge the difficulty in selecting it before the skin potential changed. Therefore, even if there is no change in skin potential, and the subject understands that he was not able to choose a kana 2.0 s later without the appearance of an SSR for the same kana, it is difficult for the subject to imagine selecting a kana again. Thus, when the subject intends to imagine selecting a kana again, the next kana has already been displayed. At the same time, SSR latency was approximately 2.6–4.2 s for the display times of 5.0, 7.5, and 10.0 s (Fig. 12). Therefore, even if the subject understands that he was not able to select a kana without the appearance of an SSR for the same kana, this is a situation in which the subject can imagine selecting a kana again. As a result, for the display times of 5.0, 7.5, and 10.0 s, we assumed that the selection accuracy increased compared with the display time of 2.5 s. At the same time, for the nontarget kana, the subject's attention would wander while the kana was displayed. Therefore, that time becomes longer so that the display time for a kana increases. This is probably the reason why unintended responses appeared so easily.

Based on these findings, we conclude that kana selection accuracy increases if the display time for the target kana is prolonged. However, at the same time, the selection accuracy also

increases for the nontarget kana. Also, according to the feedback from the subjects after the experiment, the display times of 7.5 and 10.0 s were considered to be very long. When the visual scanning system is used, it is best if the user can accurately select the kana within a short visual scanning time. In Fig. 10, it can be seen that the selection accuracy was not significantly different above the display time of 5.0 s. We believe that the optimal display time is 2.5–5.0 s based on the selection accuracy graph (Fig. 11). In fact, the average latency of all SSRs for the target kana was 3.29 ± 1.63 s. This result of the optimal display time is in accordance with the one discussed previously.

5. Optimal visual scanning speed

5.1 Outline of the experiment

In Chapter 4, we found that the optimal display time is 2.5–5.0 s. Thus, we investigated the display time to choose the optimal visual scanning speed. The experimental setup was the same as that in Chapter 4. However, the display times were 2.5, 3.0, 3.5, 4.0, 4.5, and 5.0 s, and randomly deployed. The experiment was repeated five times.

5.2 Results

Figure 13 shows the relationship between kana selection accuracy and display time. The graph shows average values ± standard error [%]. The purposeful selection accuracy, when an SSR appeared for the target kana, was 46.0 ± 5.1% (display time: 2.5 s), 56.0 ± 5.1% (display time: 3.0 s), 50.0 ± 5.5% (display time: 4.5 s), 76.0 ± 5.1% (display time: 4.0 s), 80.0 ± 7.1% (display time: 4.5 s), and 82.0 ± 3.7% (display time: 5.0 s). The accidental selection accuracy, when SSR appeared for the nontarget kana, was 2.5 ± 0.8% (display time: 2.5 s), 2.0 ± 0.9% (display time: 3.0 s), 3.0 ± 1.5% (display time: 4.5 s), 10.5 ± 2.8% (display time: 4.0 s), 8.0 ± 2.2% (display time: 4.5 s), and 8.0 ± 2.0% (display time: 5.0 s).

For both the target and nontarget kana, the selection accuracy in the display times of 2.5, 3.0, and 3.5 s was lower than that for the other display times.
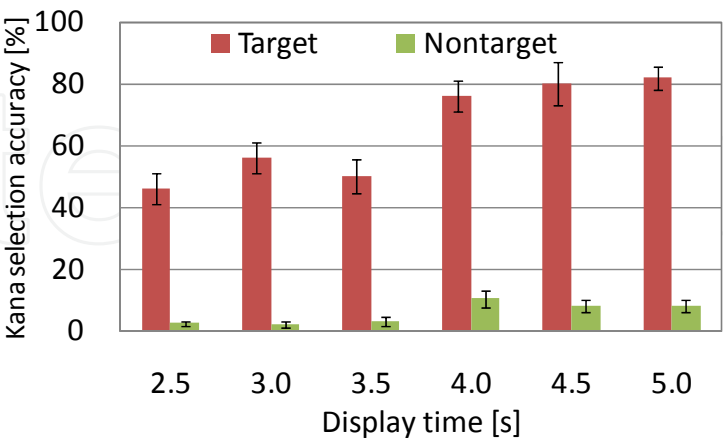

Fig. 13. Kana selection accuracy

Figure 14 shows the relationship between SSR latency and display time. The SSR latency values in Fig. 14 are averages ± standard error [s] when an SSR appeared for the target kana. An SSR was also detected when nontarget kana were displayed: this SSR was a response not

intended by the subjects. It was difficult to precisely identify the moment of stimulus onset; therefore, SSR latency was analyzed only for the target kana.

SSR latency was 2.03 ± 0.04 s (display time: 2.5 s), 2.14 ± 0.06 s (display time: 3.0 s), 2.36 ± 0.07 s (display time: 3.5 s), 2.69 ± 0.10 s (display time: 4.0 s), 3.07 ± 0.11 s (display time: 4.5 s), and 3.03 ± 0.12 s (display time: 5.0 s). The graph shows that SSR latency increases with the kana display time and that the standard error increases with the display time.
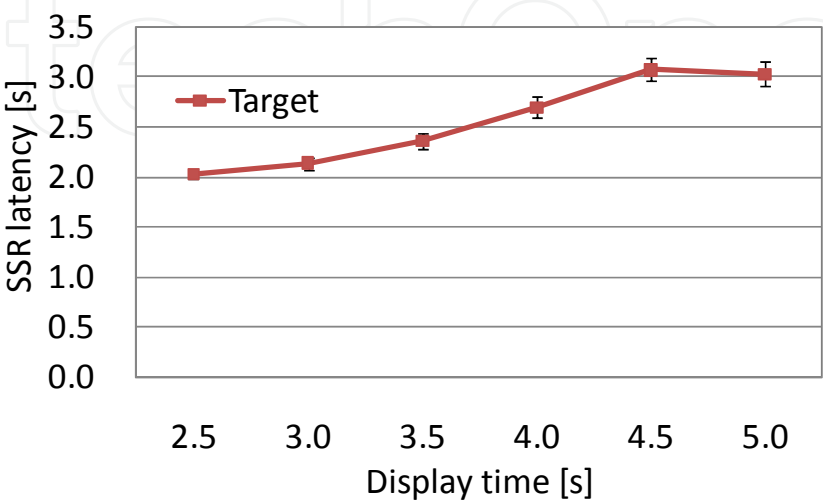
Fig. 14. Latency of SSR

5.3 Discussion

The kana selection accuracy for the display times of 2.5, 3.0, and 3.5 s was lower than that for the other display times. Similar to the results mentioned in Chapter 4, when the display time is short, even if there is no change in skin potential, and the subject understands that he is not able to choose a kana approximately 2.0–2.3 s later without the appearance of an SSR for the same kana, it is difficult for the subject to imagine selecting a kana again. For the display times of 4.0, 4.5, and 5.0 s, it is possible that even if the subject understands that he was not able to select a kana without an SSR appearing for the same kana, this is a situation in which the subject can imagine selecting a kana again.

Based on these findings, we concluded that the optimal display time is 4.0–5.0 s. For the display times of 4.0, 4.5, and 5.0 s, the kana selection accuracy was high and the latency of SSR was not very long. We can expect that kana selection will be accurate if we make a communication-assistive devise using SSR with these display times.

6. Conclusion

In this study, we indicated the possibility of using SSR as the switching of the communication aid in ALS. Additionally, we investigated the influence of the visual scanning speed on the kana selection accuracy and latency of SSR. The following results were obtained:

1. In ALS patients, we believe that it is possible to using SSR as a switching of communication assistive method.

2. Kana selection accuracy was more and SSR latency was long when the display time was long.

3. The optimal visual scanning speed is 4.0 – 5.0 seconds

If the optimal display time is set, we believe that the selection accuracy increases. In the future, we aim to investigate the optimal display time and develop a communication device based on SSR.

7. References

Baba, M.; Watahiki, Y., Matsunaga, M., Takebe, K. (1988). Sympathetic skin response in healthy man, *Electromyography and clinical neurophysiology*, Vol. 28, No.5, pp. 277-283

Damasio, AR.; Tranel, D., Damasio, H. (1990). Individuals with sociopathic behavior caused by frontal damage fail to respond autonomically to social stimuli, *Behavioural Brain Research*, Vol. 41, No. 2, pp. 81-94

Dettmers, C.; Fatepour, D., Faust, H., Jerusalem, F. (1993). SYMPATHETIC SKIN RESPONSE ABNORMALITIES IN AMYOTROPHIC LATERAL SCLEROSIS, *Muscle & nerve*, Vol. 16, pp. 930-934

Féré, C. (1888). Note sur des modifications de la résistance électrique sous l'influence des excitations sensorielles et des émotions, *Compte Rendus des Séances de la Société de Biologie et de ses Filiales*, Paris 40, pp. 217-219

Fujisawa, K.; Kakigi, S., Yamazaki, K. (1998). Electrodermal activity, In: *New physiological psychology Vol.1 Basic of physiological psychology*, pp.210-221, Kitaohji Shobou Co., Ltd., ISBN4-7628-2114-4 (Written in Japanese)

Friedrich, E.V.C.; McFarland, D.J., Neuper, C., Vaughan, T.M., Brunner, P. & Wolpaw, J.R. (2009). A scanning protocol for a sensorimotor rhythm-based brain-computer interface, *Biological Psychology*, Vol. 80, pp. 169-175

Hilz, MJ.; Axelrod, FB., Schweibold, G., Kolodny, EH. (1999). Sympathetic skin response following thermal, electrical, acoustic, and inspiratory gasp stimulation in familial dysautonomia patients and healthy persons, *Clinical autonomic research*, Vol.9, No.4, pp. 165-177

Ito, H.; Sugiyama, Y., Mano, T., Okada, H., Matsukawa, T. & Iwase, S. (1996). Skin sympathetic nerve activity and event-related potentials during auditory oddball paradigms, *Journal of the Autonomic Nervous System*, Vol. 60, pp. 129-135

Iwase, S.; Mano, T. (1996). Sympathetic skin response (SSR); 2. Clinical aspects, *Clinical electroencephalography*, Vol. 38, No. 9, pp. 643-652

Khalfa, S.; Isabelle, P., Jean-Pierre, B., Manon, R. (2002). Event-related skin conductance responses to musical emotions in humans, *Neuroscience Letters*, Vol. 328, No. 2, pp. 145-149

Knezevic, W.; Bajada, S. (1985). Peripheral autonomic surface potential. A quantitative technique for recording sympathetic conduction in man, *Journal of the neurological sciences*, Vol. 67, No. 2, pp. 239-251

Kumru, H.; Vidal, J., Perez, M., Schestatsky, P., Valls-Solé, J. (2009). Sympathetic skin responses evoked by different stimuli modalities in spinal cord injury patients, *Neurorehabilitation and Neural Repair*, Vol. 23, No. 6, pp. 553-558

Masuda, F. & Wada, C. (2005). Basic research into the environmental conditions necessary to develop a sympathetic skin response input supporting device, P*roceedings of the Society of Instrument and Control Engineers Annual conference 2005*, pp. 820-824

Masuda, F. & Wada, C. (2007). Character selection with sympathetic skin response when listening to sounds, P*roceedings of Second International Conference on Innovating Computing, Information and Control*, A01-03 (CD-ROM)

Masur, H.; Oversohl, U.S., Papke, K., Oberwittler, C. & Vollmer, J. (1995). SYMPATHETIC SKIN RESPONSE IN PATIENTS WITH AMYOTROPHIC LATERAL SCLEROSIS, *FUNCTIONAL NEUROLOGY*, Vol. 10, No. 3, pp. 131-135

Mitani, H. & Ishiyama, Y. (2008). Sweating and sympathetic skin response (1), *Clinical electroencephalography*, Vol. 50, No. 3, pp. 165-172 (Written in Japanese)

Nakabayashi, T. & Igarashi, M. (2003). The Effectiveness of Somato-switches to improbe upon the Ability of Communication for Sever multiple Handicapped – The Application of a Brain wave Switch and an Electromyographical Switch, *Human Sciences Research*, Vol. 11, No. 1, pp. 63-74 (in Japanese)

Nicotra, A.; Catley, M., Ellaway, P.H. & Mathias, C.J. (2005). The ability of physiological stimuli to generate the sympathetic skin response in human chronic spinal cord injury, *Restorative Neurology and Neuroscience*, Vol. 23, pp. 331-339

Oey, P.L.; Vos, P.E., Wieneke, G.H., Wokke, J.H.J., Blankestijn, P.J. & Karemaker, J.M. (2002). SUBTLE INVOLVEMENT OF THE SYMPATHETIC NERVOUS SYSTEM IN AMYOTROPHIC LATERAL SCLEROSIS, *MUSCLE & NERVE*, Vol. 25, pp. 402-408

Schondorf, R.; Gendron, D. (1990). Properties of electrodermal activity recorded from non palmar/plantar skin sites, *Neurology*, Vol. 40, pp. 128

Shahani, B.T.; Halperin, J.J., Boulu, P. & Cohen, J. (1984). Sympathetic skin response - a method of assessing unmyelinated axon dysfunction in peripheral neuropathies, *Journal of neurology, neurosurgery, and psychiatry*, Vol. 47, No. 5, pp. 536-542

Soliven, B.; Maselli, R., Jaspan, J., Green, A., Graziano, H., Pertersen, M. & Spire, JP. (1987). Sympathetic skin response in diabetic neuropathy, *Muscle & nerve*, Vol. 10, pp. 711-716

Tsukahara, R. & Aoki, H. (2002). Skin potential response in letter recognition task as as alternative communication channel for individuals with severe motor disability, *Clinical neurophysiology*, Vol. 113, pp. 1723-1733

Uozumi, T. & Matsunaga, K. (2000). Sympathetic skin response, In: *Autonomic nerve function test third edition*, Japan Society of Neurovegetative Research, pp. 223-226, BUNKODO Co., Ltd., ISBN4-8306-1527-3 (Written in Japanese)

Valls-Sole, J.; Monforte, R. & Estruch, R. (1991). Abnormal sympathetic skin response in alcoholic subjects, *Journal of the neurological sciences*, Vol. 102, pp. 233-237

Van den Bergh, P. & Kelly, JJ. (1986). The evoked electrodermal response in peripheral neuropathies, *Muscle & nerve*, Vol. 9, pp. 656-657

Wang, SJ.; Fuh, JL., Shan, DE., Liao, KK., Lin, KP., Tsai, CP. & Wu, ZA. (1993). Sympathetic skin response and R-R interval variation in Parkinson's disease, *Movement disorders*, Vol.8, pp.151-157

Watahiki, Y. (1987). Sympathetic skin response (SSR) – a simple quantitative method for assessing sympathetic dysfunction (1) SSR in normal man, *Clinical Neurology*, Vol.27, pp. 442-448 (Written in Japanese)

Yamashiro, D.; Aihara, M., Ono, C., Kanemura, H., Aoyagi, K., Goto, Y., Iwadare, Y. & Nakazawa, S. (2004). Sympathetic Skin Response and Emotional Changes of Visual Stimuli, *No To Hattatsu,* Vol. 36, No. 5, pp. 372-377 (Written in Japanese)

Yokota, T.; Matsunaga, T., Okiyama, R., Hirose, K., Tanabe, H., Furukawa, T. & Tsukagoshi, H. (1991). Sympathetic skin response in patients with multiple sclerosis compared with patients with spinal cord transection and normal controls, *Brain*, Vol. 114, pp. 1381-1394

Character Recognition

Edited by Minoru Mori

Character recognition is one of the pattern recognition technologies that are most widely used in practical applications. This book presents recent advances that are relevant to character recognition, from technical topics such as image processing, feature extraction or classification, to new applications including human-computer interfaces. The goal of this book is to provide a reference source for academic research and for professionals working in the character recognition field.

How to reference

In order to correctly reference this scholarly work, feel free to copy and paste the following:

INTECH
open science | open minds