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주제어
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Abstract

Archer's capability of attention and relaxation control during shooting process was evaluated using EEG technology. Attention and meditation algorithms were used to represent the levels of mental concentration and relaxation levels. Elite, mid-level, and novice archers were tested for short and long distance shootings in the archery field. Single channel EEG was recorded on the forehead (Fp1) during the shooting process, and attention and meditation levels were computed by real time. Four types of variations were defined based on the increasing and decreasing patterns of attention and meditation levels during shooting process. Elite archers showed increases in both attention and relaxation while mid-level archers showed increased attention but decreased relaxation. Elite archers also showed higher levels of attention at the release than mid-level and novice archers. Levels of attention and relaxation and their variation patterns were useful to categorize archers and to provide feedback in training.

Keywords: Attention, Relaxation, Meditation, Algorithms, Shooting Process

요 약

양궁의 슈팅과정에 대하여 정신 집중력과 긴장 이완도를 뇌파를 이용하여 평가하였다. 정신 집중과 긴장 이완 수준의 평가는 집중과 명상 알고리즘을 이용하여 수행되었다. 우수, 중급, 그리고 초급 양궁 선수들이 야외 양궁장에서 근거리와 장거리 타깃을 대상으로 슈팅 훈련을 할 때 앞이마(Fp1)에 전극을 부착한 헤드밴드 형태의 휴대용 뇌파 시스템으로 뇌파를 기록하였다. 개인별로 기록된 뇌파는 집중과 명상 알고리즘을 이용하여 실시간으로 정신집중과 긴장이완 수준이 계산되었으며, 슈팅 과정에서 정신 집중과 긴장이완 수준의 변화 형태가 분석되었다. 개인별로 각각의 슈팅에 대한 정신집중 및 긴장이완 수준 변화는 네 유형으로 분류되었으며, 이 변화 유형은 양궁 선수들의 경기력을 평가하는 신뢰성 있는 지표로 나타났다. 우수 선수의 경우 정신 집중과 긴장이완 수준이 슈팅과정의 진행에 따라 동시에 증가하는 형태로 나타났으며, 중급 선수의 경우 정신 집중도는 증가하는 반면 긴장 이완 수준은 감소하는 결과를 보여 주었다. 실시간으로 제공되는 정신 집중과 긴장 이완 수준의 변화는 양궁 선수들의 경기력 평가뿐만 아니라 훈련 시에 유익한 피드백이 되었다..

주제어: 정신 집중, 긴장 이완, 명상, 알고리즘, 양궁 슈팅 과정

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1. Introduction

1.1 Background of Study

Performance in sports is a result of physical, physiological, and psychological training, although other factors, such as equipment and environment, may affect the performance. Training of a sport generally begins with physical or biomechanical factors. It covers basic posture, body movements, and motions. Second stage of training covers physiological factors, including endurance, power, and fatigue control methods. Coaches are mainly involved in the physical and physiological training.

It is well known that high performance athletes have strong mentality in addition to their pertinent skills and physiological capabilities (Behncke[1]), Carr[2])). This strong mentality is associated with motivation, mental concentration on the game, stress and anxiety management, self-confidence, and emotion control (Young and Pain[3])). Although mental strength is an essential factor for elite athletes, there are few training methods for developing it. Instead, there are many general guidelines. Coaches are generally not involved in mental training. Mental training is considered what athletes should do by themselves or what shall be included in physical and physiological training. It is hard to develop a mental training method for a sport since mental state is invisible, different in individuals, subjective, and difficult to evaluate in training results.

It is known that static sports like shooting and archery require high levels of mental concentration. However, many dynamic sports including baseball, golf, tennis, boxing, and weight lifting also require mental concentration. Coaches tell athletes to be exclusively concentrated on the game, to have confidence, and not to worry about others. Athletes try to meet those goals. In many cases, however, athletes and even coaches do not know exactly what mental concentration is or how high the mental concentration should be increased.

There are some indices to evaluate mental concentration levels. Psycho-physiological measurements may be the best approach to evaluate mental concentration levels at the training site. However, psycho-physiological measures are complicated, require sophisticated equipment, and require time to analyze the data. Most of all, the psycho-physiological measures are vulnerable to noises. It is difficult to bring out the complicated equipment to the field and control the various noise sources. There are large gaps between experimental results in laboratories and real situations in the field.

In order to develop a mental training method and to provide training programs for each athlete, it is essential to understand the mental state of the athlete during competition. Portable or wearable systems which can be used during training or competitions would be of great use. In addition, test results should be provided to athletes and coaches in near real time.

This study is to investigate an archer's capability of mental control during the shooting process using a wearable electroencephalograph(EEG) system with attention and meditation algorithms at the archery field. In addition, it is to provide biofeedback to the archers for helping them to control their attention and relaxation during the shooting.

1.2. Attention in Archery and EEG

Archery is a sport which propels arrows with a bow to the target. Historically, archery has been used for hunting and combat. Now it has become a recreational activity and a sport. There are different types of archery, depending on the bows and game rules. Among them, target archery is the most popular worldwide, although field archery is also popular in Europe and America. The recurve bow is the only bow permitted in the Olympics. Therefore, when we talk about archery as a sport, this shall mean target archery with the modern recurve bow.

Many skills are needed to propel arrows to the

1) Mental skills training for sports: A brief review. Athletic Insight. 2004. 6(1). 1-19.
2) Sports psychology: Psychological issues and applications. Phys Med Rehabil Cli N Am. 2006. 17. 519-535.
3) The zone: Evidence of a universal phenomenon for athletes across sports. Athletic Insight. 1999. 1(3). 21-30.

target with a bow. The shooting process is the core portion of the archery skill. It starts from 'set-up' and goes through 'drawing,' 'anchoring,' 'loading,' 'aiming and expansion,' 'release,' and finally ends at 'follow-through' (Lee and de Bondt[4]). In this process, well-tuned muscle contraction, breathing control, visual aiming, and mental concentration are required. Mental concentration accompanied by visual focusing plays an especially key role in performance.

There are many types of attention. Among them, archery associates with visual attention, mental attention, and selective attention. Visual attention and mental attention are involved in the normal shooting process. In competition, since there are many noises, tensions and anxiety, selective attention in shooting becomes important. During the shooting process, mental attention may be involved first, but visual attention will play a major role at the later part of the shooting process. Therefore, shooting training should consider this transition of attentions.

Many efforts have been made to understand mental and emotional states using human brain waves. Generally, alpha waves (8 ~ 12 Hz) correlate with relaxation or rest state, while beta waves (13 ~ 30 Hz) correlate with mental concentration and active thinking. Theta waves (4 ~ 7 Hz) relate to drowsiness or early sleep, and delta waves (0.1 ~ 3 Hz) relate to deep sleep (Vernon et al.[5]). However, human brain waves generally include all of these waves and vary dynamically. Compositions of frequency bands change depending on mental and emotional states and the locations of the electrodes. Attention and meditation algorithms which were developed with these brain wave components (NeuroSky, Inc. U.S.A.) were known to useful to monitor mental attention and relaxation levels. The attention algorithm represents overall mental and visual attentions. It is sensitive to mental attention and visual focusing. The meditation algorithm shows sensitivity to eye open and close, and mental relaxation. With these algorithms, hypotheses were made; 1) when an archer focuses on the target with mental concentration, attention level will be high; 2) when an archer maintains a comfortable and calm feeling, meditation level will be high; 3) if an archer performs the shooting process with comfortable concentration, both attention and meditation levels will be high. In normal situation, with voluntary effort, when the attention level increases, the meditation level decreases.

When an archer sets up the shooting process, he/she should be clear-minded and may only look at the tip of the arrow. As the archer performs drawing, anchoring, loading and aiming and expansion, his/her visual focus needs to move from the tip of arrow to the target through the sight pin. This requires a high level of visual attention. Simultaneously, the archers should concentrate only on the shooting process and should not lose concentration by external noise or internal thought distractions like anxiety. In this study, meditation is defined as 'think nothing' except shooting. If an archer concentrates on the shooting process with visual and mental attention, and does not think about external noise, anxiety for score or other thing, his/her meditation level is expected to be high. Experiments were planned to evaluate these hypotheses.

2. Experiments

Experiments were designed and conducted to investigate variations of the archers' attention and relaxation levels during the shooting process, which requires visual and mental attention and relaxation.

Subjects were Resident Archers at the US Olympic Training Center, Chula Vista, CA, and junior archers who were attending archery camp. Two adult archers also participated in the test. A total 14 archers (9 male and 5 female) were tested. (One archer's data were not used for the statistical significance test due to small sample size.) Their ages ranged from 11 to 40 years old, and their archery training careers ranged from 0.1 to 15 years

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4) Total Archery. 2005. Samick Sports.

5) The effect of training distinct Neurofeedback protocols on aspect of cognitive performance. International Journal of Psychology. 2003. 47. 75-85.

(Table 1).

Table 1. Subject data.

Archer	Gender	Age (yrs.)	Career (yrs.)	# of Shooting analyzed
A	male	20	9	10
B	male	20	9	10
C	male	19	9	9
D	male	22	15	8
E	female	11	3	13
F	female	29	0.5	11
G	male	40	10	10
H	male	16	3.5	16
I	female	11	0.8	5
J	female	15	3	10
K	male	15	0.8	12
L	male	14	5	12
M	female	15	0.1	8
N	male	16	7	20

A single channel wearable EEG system and NeuroView™ software (NeuroSky Inc., U.S.A.) were used to record and store the brain wave signals in a computer. The EEG system was in the form of a headband with one active electrode on the forehead (Fp1) and one reference and one ground electrode on the left and right earlobes, respectively. All electrodes were dry type, hence no gel was applied to attach the electrodes. Detected EEG signals were filtered with a notch and band pass (0.5 ~ 30 Hz) filters and converted to digital data at a 128 Hz sampling rate. Noise and abnormal EEG signals, whose amplitudes exceed 100 microvolt, were also eliminated. Embedded algorithms processed the signals to compute attention and meditation levels every half second. The levels of attention and meditation were presented as a score from 0 to 100. Then, raw EEG signals and attention and meditation data were transmitted to a computer via a Bluetooth connection. The computer displayed these signals and data with digital values and analog graphics so that they could be easily monitored. The data was also stored in the computer.

Each archer shot 15 to 20 arrows to 18 meter and 70 meter targets at the outdoor archery field. Archers decided the numbers of shooting per target. For example, one archer shot 7 arrows to the 18 meter target, and 8 arrows to the 70 meter target, while another archer shot 5 arrows to the 18 meter target and 10 arrows to the 70 meter target, etc. Archers were asked to do their best to hit 10 point of target with no time limitation. Thus, there was no time stress. Brain waves were continuously recorded from the moment of drawing to one second after the release.

Figure 1. An archer in shooting process with the wearable EEG system.

When the EEG headband was put on the head of an archer and the electrodes were placed at the appropriate locations, the NeuroView™ software displayed the raw brain wave signal and attention and meditation levels on the computer monitor. The signals were observed for 2 ~ 3 minutes of aging time, and inspected whether normal EEG signal was detected. Then the archer was seated in front of computer monitor and asked to increase attention levels with voluntary effort and maintain the highest attention level as long as possible. The computer displayed attention and meditation levels using an analog clock style meters, whose needles moved from 0 to 100. Archers were said to focus on the end of the needle and to try to push the needle to the level of 100 by mental concentration. No specific instructions were given for mental concentration task. Three trials of one minute session were performed for attention. Then, the archer was asked to relax with closed eyes. They were asked not to move their eyes, to relax the upper body, and to breathe slowly. Three trials of one minute sessions were repeated. The attention and meditation levels were monitored and stored in computer. This process was for calibrating the attention and meditation algorithms and investigating whether the archer showed abnormal brain wave signals. Then, the archer was asked to stand at the shooting line and start shooting. The EEG system transmitted data to the computer via a Bluetooth connection and the distance between the archer and the computer was about 3 meters. Therefore, archers did not have any discomfort or interference in shooting caused by the headband or test equipment.

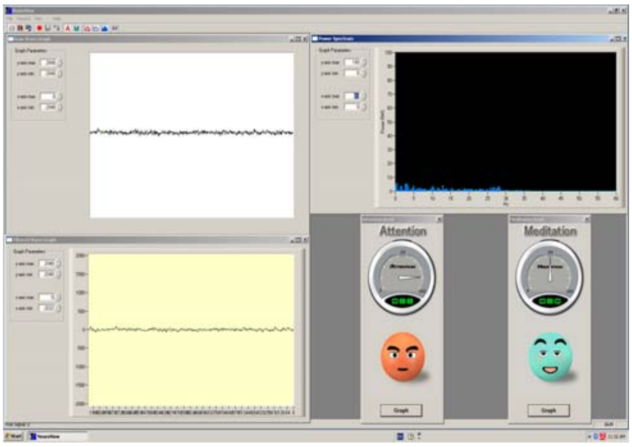

Figure 2. Computer display for EEG monitoring

Archers shot the short distance first, and moved to long distance. They shot 3 to 5 arrows, collected the arrows from the target and repeated the shooting for 15 to 20 arrows. After each shooting session, a brief feedback on attention and meditation levels and eye blinks based on raw EEG was given to the archer. Archers could make comments on their shots between sessions. No special instructions for shooting skill or method were given. Digitized raw EEG and attention and meditation levels from the moment of drawing to one second after release were stored in the computer.

3. Analyses and Results

Stored data of the raw EEG, attention and meditation values for each shooting of the all archers were graphically presented and reviewed (Figure 3).

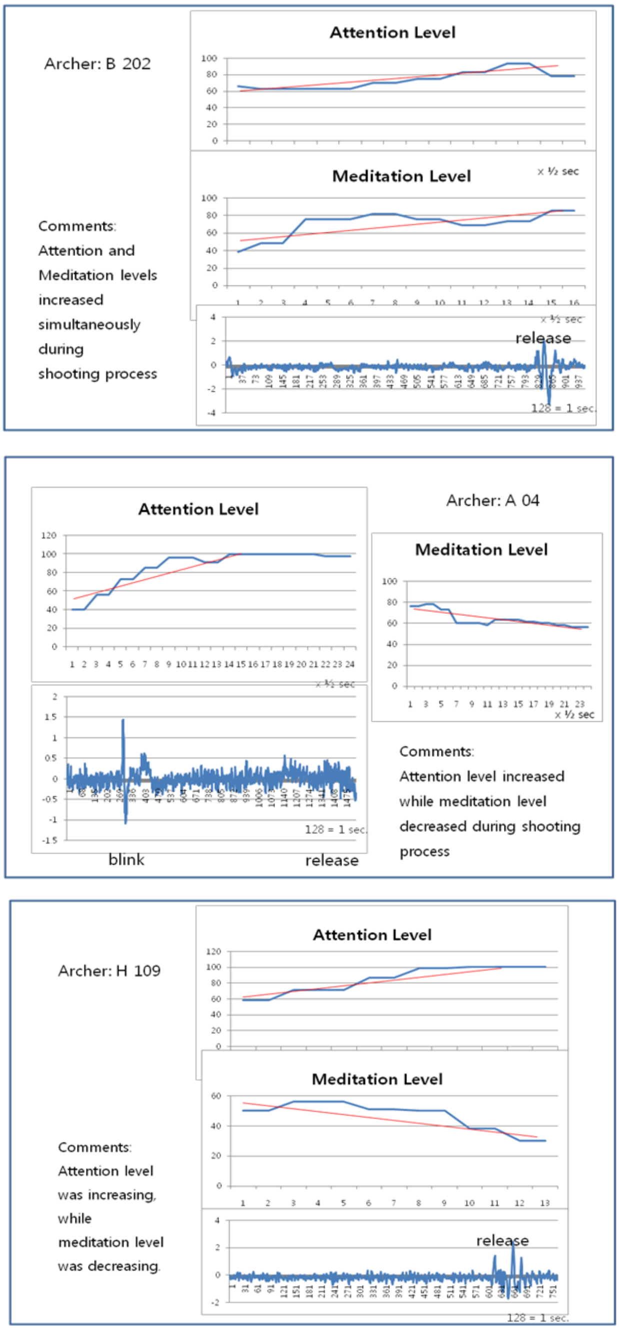

Figure 3. Examples of raw data analysis. Increase of attention level accompanied either increase of meditation or decrease of meditation depending on archer and shooting conditions.

Variations of attention and meditation levels were investigated with raw EEG graphs. Patterns and trends of the variations were analyzed. Some data was lost or contaminated with noise caused by electrode contact problems during the tests. If a part of data was lost or contaminated over 50%, the data of the shooting was eliminated from analysis. Thus this test became an unequal sample size design (Table 1). Mean values of attention and meditation levels were computed for each shot. Then, the grand means of these values were computed for every archer. Levels of attention and meditation at the moment of release were also read and compared with their mean values. Linear regression analyses were performed for the variations of attention and meditation for each shot. Although duration of shooting process varied in shots and in archers, time (in half second since attention and meditation level data were collected every half seconds) was used as independent variable of the linear regression. In linear regression analysis, intercept, averaged deviation and correlation coefficient as well as slope were computed using a MATLAB® program. However, since this study was interested in the slope, the variation patterns, analysis was focused on the slope. Numbers of positive and negative slopes were counted for each archer. Then, means of the slopes were computed for attention and meditation. Correlation coefficients were computed between the variations of attention and meditation in each shot. Numbers of positive and negative correlations were counted for each archer. The results are summarized in Table 2.

Table 2. Summary data of experimental results.

Archer	Attention (mean)	Attention (at release)	Meditation (mean)	Meditation (at release)	Slope, mean (attention)	Slope, mean (meditation)	# of + correlation	# of – correlation	# of Type I variation	# of Type IV variation
A	70.18	79.20	51.05	51.60	3.70	1.60	7	3	5	0
B	74.78	93.08	55.09	58.92	5.72	0.91	6	6	7	0
C	75.99	86.0	69.40	74.33	5.04	2.12	5	4	6	0
D	59.53	73.13	67.64	84.75	6.03	4.27	5	3	5	0
E	53.64	70.16	55.10	54.92	5.67	-0.15	5	8	4	1
F	91.66	96.82	45.90	43.0	1.44	-1.21	3	8	3	1
G	78.13	87.80	66.98	66.70	4.31	0.22	3	7	4	0
H	64.69	72.50	42.27	36.81	4.65	-5.19	3	13	1	3
I	59.68	65.40	55.11	57.20	1.85	-1.75	1	4	1	0
J	69.22	74.20	50.38	51.0	0.91	0.40	4	6	1	2
K	78.74	80.75	43.81	49.67	1.51	1.26	2	10	3	0
L	61.24	62.75	51.84	50.50	0.71	-0.86	5	7	0	2
M	79.51	81.25	48.48	51.63	-0.61	0.14	2	6	1	1
N	56.52	55.45	57.17	55.65	-0.37	-0.01	10	10	2	5

ANOVA tests were performed independently for attention and meditation data for investigating differences in attention and meditation among archers. Since numbers of data for archers were different it became a single-factor unequal sample size design. ANOVA showed there were significant difference (α = 0.01, df = 12, 138) in attention (F = 4.537) and meditation (F = 6.797) levels among archers.

As a post-hoc analysis, Neuman-Keuls tests (Winer[6]) were used for grouping the archers of no differences in attention and meditation levels, from the highest to the lowest. Results of Neuman-Keuls test (α = 0.01) are summarized in Figure 4.

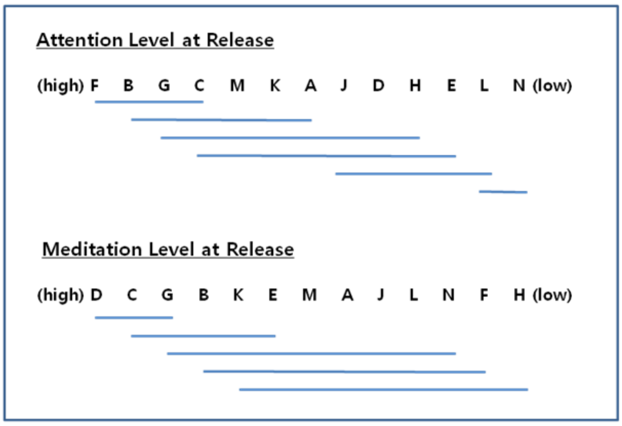

Figure 4. Results of Neuman-Keuls tests.

In the result of Neuman-Keuls test, subjects underlined by a common line do not differ from each other; subjects not underlined by a common line differ from others. Therefore, attention level of Archer F does not differ from those of Archers B, G and C, but differ from those of M, K, A, J, D, H, E, L and N. Similarly, the meditation level of Archer D does not differ from those of Archers C and G; but differ from those of Archers B, K, E, M, A, J, L, N, F, and H.

Variation patterns of attention and meditation levels were investigated with their mean values and slopes of the linear regression equations. Four types of combined variations of attention and meditation levels were defined; Type I variation represents increase in both attention and meditation levels during the shooting process; Type II variation represents increase in attention but decrease in meditation; Type III variation represents decrease in attention and increase in meditation levels; and Type IV variation represents decrease in both attention and meditation during the shooting process. (Figure 5)

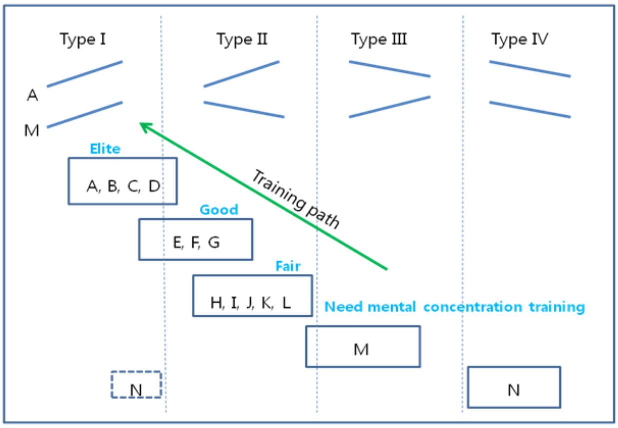

Figure 5. Variations of Attention and Meditation levels during shooting process.

Then each archer's variation patterns of attention and meditation during shooting were compared to these categorized patterns. Information on skill level of the archers was provided by the US Archery national team coach based on each archer's performance represented by scores in games.

Although archers showed varying patterns of attention and meditation levels, trends were apparently visible among the skill level groups. The elite archer group (A, B, C and D) showed more positive correlations between the slope of attention and that of meditation. They also showed more Type I variations than any other groups (table 2). It means that they could increase attention and meditation levels simultaneously during the shooting process.

The second group of archers (E, F, and G) had several Type I variations but mainly Type II variations. They showed more negative correlations between attention and meditation variations than the elite group. This implies that attention was increased while meditation level was decreased during the

6) Statistical principles in experimental design (2nd ed.). McGraw-Hill. 1971.

shooting process. They might be briefly distracted by external noises and/or have 'noisy' thinking.

The third group of archers (H, I, J, K and L) mainly showed the Type II variations. They rarely made Type I variations and there were more negative correlations between the slopes of attention and those of meditation. They could do concentration but not be concentrating only on the shooting. They might not be confident to their shooting skills.

Archer M was a novice, and she could not control her attention and meditation levels during the shooting process. Archer N showed interesting results. He showed Type IV variations. His shooting process time was short, and his attention and meditation levels decreased as time went by. However, when he extended the shooting process time and performed the shooting process step-by-step, he showed Type I variations.

These results provide valuable information on characteristics of elite archers and on the training path for the novice and intermediate group archers.

4. Discussions

Archery has been known as a mental sport, which requires high levels of attention. In competitions, archers should repeat shooting for a long time, and every shot requires high attention. For good performance, i.e., high score, stable position and posture, consistent movement, and precise shooting skills are also required. These physical and physiological factors can be effectively trained with experienced coaches. Many biomechanical apparatus can provide precise information on the posture, body movement, and other skills of shooting. Still there are many factors that affect an archer's performance. External factors include wind, noise and other environmental conditions. Internal factors include mental and emotional conditions, physiological heath and muscle fatigue. Eventually, these factors affect mental attention and feeling of comfort. Mental attention is highly correlated with visual attention or focusing (Desimone[7]). If an archer concentrates only on the shooting with focusing on the target, he/she may not give any attention to external and even internal noises. He/she may feel comfort in body and mind and have confidence in his/her shooting. This state can be defined as attention with comfort and aids archers to shoot consistently.

Experimental results showed that elite archers increased both attention and meditation during the shooting process (Type I variation). Their attention and meditation levels reached the highest value at the moment of release. It means that they could concentrate on the shooting process with a comfortable feeling, and release the arrow without hesitation or anxiety. If they thought something, such as unstable aiming, noise from audiences, or other archers, their attention and meditation levels decreased. Sometimes, even elite archers showed increasing attention with decreasing meditation level. This happened especially in long distance shooting, which is more difficult for aiming and focusing on the target. Many archers did not realize their attention level was decreased by the short 'thought' of other things except shooting (Manoilov[8]). Shooting training with biofeedback will be helpful for the archers to be aware of this change and to control their attention and relaxation skills.

Mid-level archers showed increasing attention and decreasing meditation level (Type II variation) during the shooting process. It means they could concentrate on the shooting with visual and mental attention, while they were still thinking something or wondering about the shooting. They might not be comfortable or confident to their shooting process. When they were asked not to worry about the score but to only concentrate on the shooting process and release like flow, they showed Type I variation in attention and meditation. With biofeedback using EEG they became aware of their mental state during the shooting process.

Type III and IV variations were shown from a

7) How the brain pays attention. Forum for the Future of Higher Education. 53-56. 2007.

8) EEG power spectrum analysis during mental task performance. International Conference on Computer Systems and Technologies. IIIA.4-1~IIIA.4-6. 2006.

novice archer who trained for only one month, and a mid-level archer who had the attention deficit disorder (ADD), respectively. The archer with ADD did not concentrate on the shooting process nor visual focusing and was not at ease, thus showing Type IV variation in attention and meditation. He shot only with his experience and could not manage his mentality. However, when he performed the shooting process step-by-step with efforts toward visual focusing to the target, his attention and meditation levels during shooting process showed Type I variation. He then realized this difference of attention levels and could repeat the shooting process with attention.

The experiment in this study was not strictly controlled. Archers decided the number of arrows for each distance by themselves. Young and novice archers shot more arrows for short distance. There was a large difference in performance levels among the archers, but the purpose of the experiment was to investigate their capability of mental control during the shooting process not to evaluate their scores. If the experiment was performed only for a long distance (70 meters) for all archers, the difference of attention and meditation level variations between the elite and mid-level archers would be much more apparent.

A German group (Herbath et al.[9]) evaluated and compared mental states of expert and novice golfers using brain wave analyses. They recorded EEG from 9 locations during putting and rest state, and found that EEG power spectra were different between expert and novice golfers. In experts, frontal theta showed more power during putting compared to the rest state. High alpha (9.75 ~ 12.5 Hz) from parietal area showed higher power in rest state than in putting task. No significant differences were shown from the novices. This result implies that the experts could control their mental states. This control capability comes from subconsciousness rather than voluntary effort. Continuous training and self confidence which can be obtained through the training are considered the main factors of the control capability. This may associate with the concepts of 'zone' and 'flow' in sports psychology (Young and Pain[10]).

In brain-computer interface (BCI) technology, there are many efforts to remove artifacts from EEG signals. Typical artifacts in raw EEG are generated by eye blinks, facial muscle tension, jaw clenching, and head movement (Halder et al.[11]). Recorded EEG signal from the forehead is very sensitive to these sources of artifacts. The headband EEG system processed the brain wave with analog and digital filters for computing attention and meditation levels. Simultaneously, raw EEG could be displayed and stored. The raw EEG signal including these artifacts provided much information on the archer's behavior during shooting. Archers can be trained not to blink eyes, to relax facial muscles, and not to move the head during shooting, as these movements affect the attention level. Thus the raw EEG signals including these artifacts were useful in providing biofeedback to the archers.

Experimental results and other studies provide a goal of mental state for shooting process in archery: high levels in both attention and relaxation (Figure 5). Neurofeedback may be helpful to the mental training. More studies with well-controlled experimental design including performance measures and follow up are needed.

5. Conclusion

The attention and meditation levels and their variation patterns measured from the archers' EEG during the shooting process were useful to categorize elite, mid-level and novice archers as well

9) Neuromonitoring in a golf putting task: Discrimination of skill level in different conditions. In Beek P, van de Langenberg R (ed.): European Workshop on Movement Science - Mechanics, Physiology, Psychology. 2007.

10) The Zone: Evidence of a universal phenomenon for athletes across sports. Athletic Insight, 1(3). 21-30. 1999.

11) Online artifact removal for brain-computer interfaces using support vector machines and blind source separation. Computational Intelligence and Neuroscience. 1-10. 2007

as to evaluate attention and relaxation levels of archers in shooting process. The integrated information from the raw EEG signals and variations of attention and meditation levels provided useful feedback and training paths to archers. The archers and coaching team reported on this EEG biofeedback "will not only help us but also athletes to reach their highest potential." (US Archery Association[12]).

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