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Accuracy in Archery Shooting is linked to the Amplitude of the ERP N1 to the Snap of Clicker

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Abstract

An archer requires a well-balanced and highly reproducible release of the bowstring to attain high scores in competition. Recurve archers use a mechanical device called the "clicker" to check the draw length. The fall of the clicker that generates an auditory stimulus should evoke a response in the brain. The purpose of this study is to evaluate the event-related potentials during archery shooting as a response to the fall of the clicker. Fifteen high-level archers participated. An electro cap was placed on the archers' scalps, and continuous EEG activity was recorded (digitized at 1000 Hz) and stored for off-line analysis. The EEG data were epoched beginning 200 ms before and lasting 800 ms after stimulus marker signals. An operational definition has been developed for classifying hits corresponding to hit and/or miss areas. The hit area enlarged gradually starting from the centre of the target (yellow: 10) to blue (6 score) by creating ten hit area indexes. It is found that the snap of the clicker during archery shooting evokes N1–P2 components of long-latency evoked brain potentials. N1 amplitudes are significantly higher in hit area than that of miss areas for the 2nd and 4th indexes with 95% confidence intervals and 90% confidence intervals for the 1st and 3rd indexes with 90% confidence intervals. We conclude that the fall of the clicker in archery shooting elicits an N1 response with higher amplitude. Although evoked potential amplitudes were higher in successful shots, their latencies were not significantly different from the unsuccessful ones.

Keywords: *archery, evoked brain potentials, auditory evoked brain potentials, n1-p2 component, archery performance*

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Introduction

Understanding the basic neural processes that underlie complex higher-order cognitive operations and functional domains is a fundamental goal of cognitive neuroscience (Light et al., 2010). Electroencephalography (EEG) is the neurophysiological method of recording the electrical activity generated by the brain via electrodes placed on the surface of the scalp (Woodman, 2010). Many EEG researchers utilize an event-related potential (ERP) experimental design in which a large number of time-locked experimental trials are averaged together, allowing the investigator to probe sensory, perceptual, and cognitive processing with millisecond precision (Light et al., 2010). ERPs are EEG changes that are time-locked to sensory, motor, or cognitive events that provide a

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safe and non-invasive approach to studying the psychophysiological correlates of mental processes. They can be elicited by a wide variety of sensory, cognitive, or motor events (Sur & Sinha, 2009).

Cheron and colleagues (2016) observed that the brain dynamics that determine both motor control and crucial psychological factors, such as intrinsic motivation, selective attention, goal setting, working memory, decision-making, positive self-concept, and self-control, need to be taken into account for top performance in sports. Being aware of this, sports professionals (e.g., sport scientists, coaches, mentors, etc.) have become interested in brain imaging, both as a route to a better understanding of the basic mechanisms underlying sporting behaviour, and as a means to develop new methods to enhance performance (Park et al., 2015).

Archery is a static sport with a stable sequence of movements throughout the shot. Archers perform a proper stance position and draw the bowstring with a three-finger hook. As they reach the final drawing position, they need to synchronize aiming, drawing and the draw length. A device called “clicker” has been developed to make a draw length check. When the clicker snaps against the bow handle, it creates a “click” sound. After sensing the clicker’s signal, the archer relaxes the flexor group muscles of the forearm and actively contracts the extensors to produce the release (Ertan et al., 2003).

Some studies have analysed brain electrical activity during archery shooting (Salazar et al., 1990; Landers et al., 1991; Landers et al., 1994). However, there is no study evaluating the response to the fall of the clicker in the human brain in the literature. The electrical activity of the archers’ brain was also not measured in the field setting until now. The snap of the clicker, which is an exogenous acoustic stimulus, is expected to evoke N1-P2 components of the long latency ERPs that should also be obtained in the field. The present study, therefore, aimed to investigate the ERPs in Recurve Archery, more specifically the N1-P2 components, and to determine if they have any relation with successful and unsuccessful shots. It is hypothesized that the amplitude of the N1-P2 components will be higher in successful shots going to the centre of the target.

Methods

An experimental research study has been designed to evaluate the responses of archer’s brain to the event in recurve archery shooting. The brain responds to the fall of the clicker paired with the hit on the target. The hits and the corresponding brain responses were grouped as successful and unsuccessful shots and their corresponding brain responses.

Participants

All participants were informed about the possible risks associated with the experiment before the commencement of the trial. This study was approved in advance by the Medical Ethical Committee of Baskent University, Medical Faculty Ankara (Certificate No: 2004/85). Informed consent was obtained from all individual participants. The study conformed to the ethical requirements of the 1975 Helsinki Declaration. The participants of the present study were 15 archers (9 males; 6 females) for archery shooting experiments. The mean age of the archers was 22.8 years (range 16–31 yrs.). The mean years of archery experience and the highest FITA scores were 5.8 years (range 2–14 yrs.) and 632 (70 m score: range 602–661), respectively.

Archers performed twelve trial shots to become acquainted with the measurement conditions before the main experiment. All participants reported normal hearing, had medical histories free of significant neurological problems and were not taking medication known to affect brain activity.

Procedure

Shootings were performed from 18 m, which is the official competition distance to the target’ face (WA, 2019). Continuous EEG activity of each subject recorded at a 1000 Hz sampling rate during the test and stored for off-line analysis (Picture 1).

PICTURE 1. The placement of the electro cap on the scalp of an archer in the field setting

As the arrow was pulled beyond the clicker, the clicker-lever fell on the bow-handle, which conveyed the signal to the archer that the arrow was appropriately positioned and is ready to be released (Ertan et al., 2003; Ertan et al., 2005a). A mechanical switch was attached under the clicker to superimpose the fall of the clicker with the EEG recordings. The

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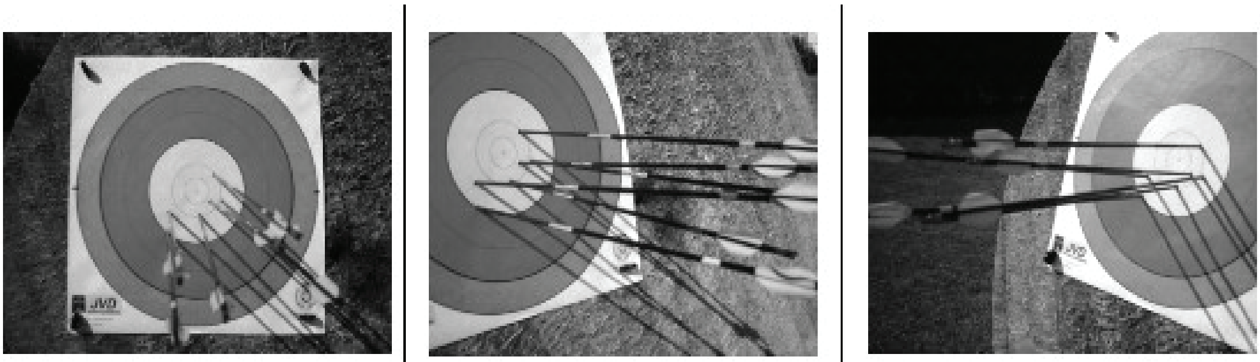
Table 1. Number of arrows shot by each participant and the calculation of hit and miss areas

Area Index	kx= ky=	Hit/ Miss Area	Participant															
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
			Number of Shots for Each Participant															
			70	72	72	72	72	72	72	72	72	72	72	64	72	72	72	1070
1	0.3 0.3	Hit	2	4	4	6	2	4	8	2	5	5	2	6	5	5	5	65
		Miss	68	68	68	66	70	68	64	70	67	67	70	58	67	67	67	1005
2	0.4 0.4	Hit	4	5	5	12	4	9	10	4	11	5	7	9	6	11	6	108
		Miss	66	67	67	60	68	63	62	68	61	67	65	55	68	61	68	962
3	0.5 0.5	Hit	7	9	6	16	8	14	14	6	19	8	17	10	10	15	11	169
		Miss	63	63	68	56	64	58	58	68	53	64	55	54	62	57	61	901
4	0.6 0.6	Hit	12	13	10	19	13	18	19	9	20	17	19	16	13	18	16	232
		Miss	58	59	62	53	59	54	53	63	52	55	53	48	59	54	56	838
5	0.7 0.7	Hit	17	19	14	24	19	21	25	14	24	27	21	18	18	28	24	313
		Miss	53	53	58	48	53	51	47	58	48	45	51	46	54	44	48	757
6	0.8 0.8	Hit	23	20	19	32	20	23	30	19	27	28	22	20	25	35	26	369
		Miss	47	52	53	40	52	49	42	53	45	44	50	44	47	37	46	701
7	0.9 0.9	Hit	28	26	25	35	22	27	33	30	32	32	25	26	33	38	32	444
		Miss	42	46	47	37	52	45	39	42	40	40	47	38	39	34	40	626
8	1.0 1.0	Hit	34	34	30	37	27	34	37	34	37	36	31	34	35	42	36	518
		Miss	36	38	42	35	45	38	35	38	35	36	41	38	37	30	36	552
9	1.1 1.1	Hit	38	40	38	39	34	40	39	39	44	42	34	36	40	48	39	590
		Miss	32	32	34	33	38	32	33	33	28	30	38	28	32	24	33	480
10	1.2 1.2	Hit	41	44	42	41	42	45	44	43	45	48	40	41	44	51	41	652
		Miss	29	28	30	31	30	27	28	29	27	24	32	23	28	21	31	418

Note: 15 participants shot a total of 1070 arrows. The first archer, for example, shot 70 arrows. Area index starting from the most central (Area Index 1) to the outer surface of the target face (Area Index 10). The first archer shot 2 arrows to the centre (hit area) and 68 arrows outside the hit area of the target in Index 1. The hit area increased gradually and the ERPs corresponding to hit and miss area compared. Please refer to Pictures 2 and 3 for calculation of hit and miss areas and Figure 2 for demonstration of the hit and miss areas and gradual increase of hit area. Figure 2 also illustrates the grand mean averages of ERPs corresponding to the hit and miss area.

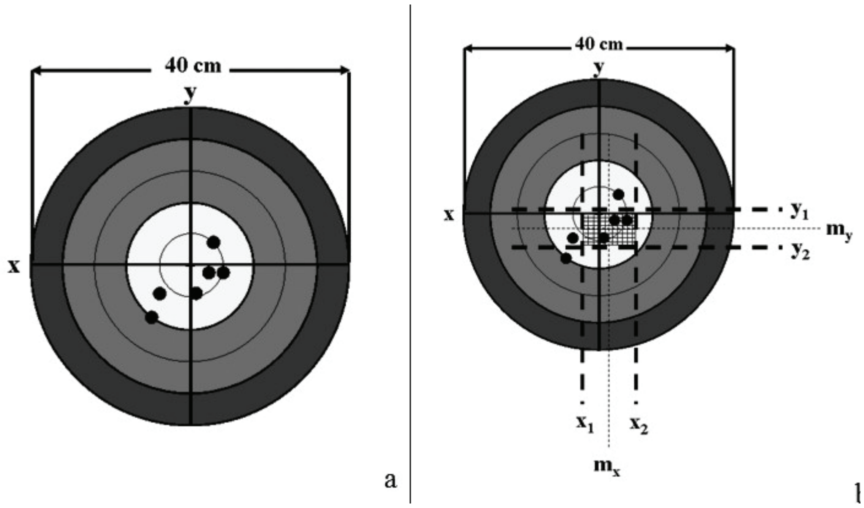
archers shot 1070 arrows in total (Table 1). The order of shots was controlled by assigning colours and numbers on each arrow, which was necessary to comprehend the exact order of each arrow to pair the shots with EEG traces.

Photos were taken on the target face after each found of shooting. The front view of the picture was used to decide the place of the arrow on the target (Picture 2a). Moreover, two more photos were taken for each end from both sides to use to determine hits on the target face accurately (Picture 2 b and c). Hits of an archer in each end were processed by placing them on a coordinate system for further analysis (Picture 3). All these hits were paired with their temporally matched single sweeps of EEG recordings. Finally, hits were grouped as falling into the hit-area and miss-area with their corresponding EEG recordings.



a b c

PICTURE 2. The processing of the hits on the target (a) front view of the hits that is used for analysis, (b) left view and (c) right views were used for determining the order of shot.



PICTURE 3. Processing the hits on the target by placing them on the coordinate system and grouping them as being in hit-area and miss-area.

The hit-area is defined as the rectangle between (x_1, y_1), (x_1, y_2), (x_2, y_1), (x_2, y_2) and the miss-area is the outer part of the hit-area on the target face (Picture 3b). Hits on the target were divided into two areas: hit-area and miss-area according to the formula given below:

$x_1=m_x - k_x$
$x_2=m_x + k_x$
$y_1=m_y - k_y$
$y_2=m_y + k_y$, where
m_x: mean of x-values of hits
m_y: mean of y-values of hits
k: a positive real number

The hit area was increased and/or decreased by changing the k_x and k_y values. The number of arrows was summarized corresponding to hit and miss areas for different values of k_x and k_y; they are shown in Table 1. Comparisons of successful and unsuccessful shots were made by assigning real numbers to k_x and k_y, respectively. For example, when "0.3" assigned to both k_x and k_y, the total number of arrows in the hit and miss area were calculated as 65 and 1005 respectively out of the total number of 1070 shots. The EEG traces coinciding with hit area were compared with that of the traces of the miss area.

EEG Recordings

The EEG was recorded with Ag/AgCl electrodes mounted in an elastic cap (Electro-Cap). A recording gel (Electro-Gel, a product of Electro-Cap International, Inc.) was injected into the electrodes. Impedances were below 5KΩ in all electrode sites. The EEG derivations (scalp sites) that were used were based on the "International 10-20" system (Jasper, 1958) and recent guidelines of the Society for Psychophysiological Research (Pivik et al., 1993) for EEG/ERP research (Fp1, Fp2, F3, F4, F7, F8, Fz, C3, C4, P3, P4, Pz, T3, T4, T5, T6, O1, O2, Right Mastoid, Left Mastoid).

Data Processing

The EEG data were epoched beginning 200 ms before and lasting 800 ms after the fall of the clicker. Each epoch was bandpass filtered (1–12 Hz, Butterworth 12 dB/oct slopes). The maximum amplitudes and peak latencies of the auditory N1 and the P2 ERP components were measured manually using the signal-processing tool in Matlab. Considering the supratemporal cortical origin and tangential dipolar orientation of the N1-P2 component of ERPs (Naatanen and Picton, 1987), the M_2 electrode was chosen to be the site of measurement for both N1 and P2 referenced to Cz (Golob et al., 2002).

Statistical Analysis

The means of the N1 amplitudes, N1 latencies, P2 amplitudes, and P2 latencies for each index and the hit-miss mean values for each area were calculated. Confidence Intervals (CIs) used to evaluate the ERPs corresponding to hit and/or miss areas N1 and P2 amplitudes and latencies respectively; 95% and 90% confidence levels were selected for each index and ERP component. The lower and upper limits of the mean ERPs difference between the hit and miss areas are given. When the CI does not include the value of zero effect, it is assumed that there is a statistically significant result in between ERPs corresponding to hit and miss areas (Du Prel, et al., 2009).

Results

Figure 1 shows the differences for the N1 amplitude (A), N1 latency (B), P2 amplitude (C) and P2 latency (D) for ERP differences between hit and miss areas. If CI does not include the value of zero effect, it was assumed that there is a statistically significant difference for any of confidence levels. When the value 0 is within 95% CI or 90% CI separately, the differences of the mean ERPs between the hit and miss areas are found to be not significant. The significant differences were observed when the value 0 is outside 95% or 90% CIs in between ERPs corresponding to defined target areas.

Figure 1A illustrates the comparison of N1 amplitudes for hit and miss areas. N1 amplitudes are significantly higher in hit area than that of miss areas for the 2nd and 4th indexes with 95% CI and the 1st and 3rd with 90% CI. There is no significant difference between the means of N1 latencies (Figure 1B), P2 amplitudes (Figure 1C) and P2 latencies (Figure 1D) for any of the area indices, as value 0 (zero) is within the CIs in all of them.

Figure 1 also compares ERP components recorded during archery shooting for the hit and miss areas defined earlier. It includes the N1 amplitudes, N1 latencies, P2 amplitudes,

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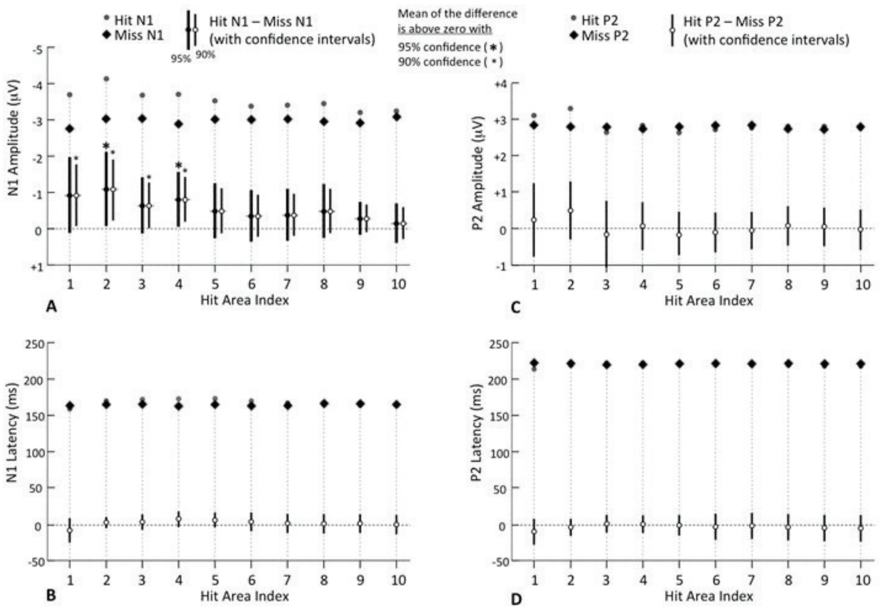

FIGURE 1. Confidence intervals of the N1 amplitudes, N1 latencies, P2 amplitudes and P2 latencies for the ERPs associated with hits and misses. The N1 amplitudes, N1 latencies, P2 amplitudes and P2 latencies for the ERPs associated with hits and misses are given as the difference between these means for each of the area indexes shown by empty circles with confidence intervals around them. Hit area indices increase as the hit area is enlarged from centre to outer surface of the target. The differences of the means are shown with the 95% and 90% confidence intervals for each index and ERP component.

and P2 latencies of the ERPs. As the hit area is enlarged, the number of arrows and their paired EEG traces increases corresponding to the hit area. The reader should refer to Table 1 for the exact number of arrows and their paired EEG traces for each participant and the whole group the hit and miss areas defined earlier. Figure 2 shows grand averaged ERPs, which were aligned to the N1 wave in order to emphasize the N1 amplitude difference between the hit and miss shots.

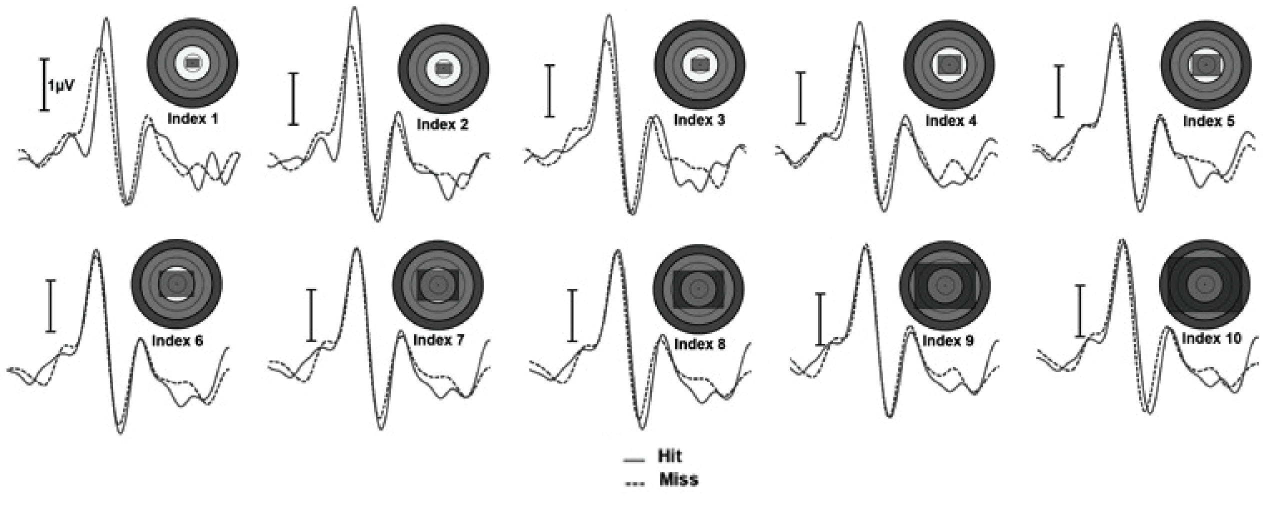

FIGURE 2. Grand averages of ERPs, which were aligned to N1.

Our results show that we can reject the null hypothesis for the N1 amplitudes corresponding to the 2nd and 4th indexes with 95% CI and the 1st and 3rd with 90% CI. We failed to reject the null hypothesis for all of the N1 amplitudes except for the 1st to 4th indexes, N1 latency, P2 amplitude, and P2 latency.

Discussion

There are some studies analysing brain electrical activity during archery shooting (Salazar et al., 1990; Landers et al., 1991; Landers et al., 1994). However, there is no study in the literature evaluating the response in the human brain to the fall of the clicker. Therefore, the purpose of the current study was to investigate the archers' brain responses to the fall of the clicker, as it is a sound that creates long latency ERPs. Pilot studies of our research group have shown that response to the event (fall of the clicker) evokes the N1-P2 component. However, it is not very well established whether there is any difference between the responses to the event during successful (hit area) and unsuccessful (miss area) shots in terms of amplitude and latency profiles. Ten different success areas have been defined by enlarging the defined area starting from the centre of the target face to the outer parts of it. The hits in the hit area and their corresponding EEG traces were compared if there is any difference between these two area responses. The 15 ar-

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chers made a total of 1070 shots during the measurements. All these shots were matched with the single sweeps of EEG recordings. Finally, hits were grouped as falling into the hit-area and miss-area with their corresponding EEG recordings. Thus, ERPs were achieved corresponding for hit and miss areas separately.

The findings have proved that when the archers shoot to the centre of the target, their N1 amplitudes are higher than that of the N1 amplitudes corresponding to the hits in the outer surface of the hit area. Therefore, a question arises regarding what the reason may be for the N1 amplitude increase. Why is the N1 amplitude higher when archers shoot in the centre of the target? We will attempt to discuss the reason(s) by referring to the studies related to N1-P2 specifications.

When an archer reaches full draw position, he/she continues aiming at the target while simultaneously drawing the bowstring. The bowstring is released when an impetus is received from a device called "clicker". Each arrow can be drawn to an exact distance, and a release can be obtained and maintained by this device. The clicker is reputed to improve the archer's score and is used by all target archers (Leroyer et al., 1993; Ertan et al., 2011). The archer should react to the clicker as quickly as possible, and synchronize the muscle activity of the whole body to attain eventual optimal accuracy. In particular, there should be a repeated contraction and relaxation of archery-specific muscle groups during archery training and competitions according to the high number of arrows (Ertan et al., 2003).

The fall of the clicker creates a "click" sound when it falls from the tip of the arrow and hits the bow handle. Its mechanical fall also generates some vibrations on the bow handle that may be sensed by archer through the bow arm palm and fingers. Therefore, as the fall of the clicker is considered to be a stimulus evoking some brain potentials, this response may not be a simple one, which is evoked by an isolated stimulus. The brain response to the fall of the clicker was thought to be a combination of auditory, tactile and/or visual stimulus response. It should also be kept in mind that during the full draw and aiming, the archer is in full concentration and his/her attention is directed to some selected cues, such as the target and the clicker's fall (Ertan et, al., 2005b).

We found that the fall of the clicker evokes N1-P2 components of ERPs in archery. Several different cerebral processes contribute to the N1 wave of the scalp-recorded ERPs (Näätänen & Picton, 1987). The N1 wave of the ERPs was larger when the participant was reacting with the stimuli than ignoring them (Woodman, 2010). An increased attentiveness level of a subject is reported, causing a higher amplitude of N1 and a lower amplitude of P2 (Crowley & Colrain, 2004). When considered to be the behavioural and cognitive processes of selectively concentrating on a discrete aspect of information, while ignoring other perceivable information, attention is accompanied by a general and nonspecific increase in cerebral excitability, which might increase the amplitude of the N1 wave (Light et al., 2010).

Temporal and event uncertainty is also known to increase the N1 amplitude (Klemmer, 1956). In addition, the responses to probe stimuli presented during tasks other than fore-period reaction time paradigms have also suggested that arousal enhances the N1 amplitude (Eason & Dudley, 1971; Picton et al., 1979). The N1 evoked by unattended auditory stimuli is also found to be larger at higher levels of alertness, as estimated on the basis of the pre-stimulus EEG (Woodman, 2010). Moreover, Wilkinson et al. (1966) demonstrated that increasing motivation by making the amount of monetary reward dependent on performance has resulted in enhanced N1 amplitudes and better performance (Wilkinson & Morlock, 1966; Furley et al., 2017).

The archer pushes the bow handle with the extended arm and pulls the string with a three-finger hook on the drawing arm. When he/she reaches the final position, the archer should accomplish and/or synchronize some tasks at the same time. As long as the archer pulls the point of arrow beyond the clicker, the onset of the click sound cannot be considered like pressing a button and/or delivering the stimuli by a machine. The archer receives foreknowledge of the timing of the stimulus from the vibrations on the tip of the arrow. However, the timing of the onset of the trigger is not totally under the control of the archer. The mentioned temporal and/or time uncertainty of the timing of the stimulus may have caused an increase in the N1-P2 amplitude. The rather high amplitude of the N1-P2 response, which would not have been expected to be elicited by a relatively weak sound like the one created by the clicker, may be explained by the findings of earlier studies reporting larger N1 amplitudes when there is uncertainty in stimulus timing (Volosin et al., 2016). The observation that the N1 latency is longer for stimuli with timing uncertainty, which is reported in the same study, may also explain the relatively longer latency of the N1 in the present study.

As for the effect of prior preparation for performing a demanding task, one should understand the details of archery shooting to explain the effect of the type of task on ERPs. An archer pushes the bow with an extended arm, which is statically held in the direction of the target, while the other arm exerts a dynamic pulling of the bowstring from the beginning of the drawing phase until the release is dynamically executed (Leroyer et al., 1993; Simsek et al., 2018). The release phase must be well balanced and highly reproducible to achieve commendable results in a competition (Ertan et al., 2011). The archer should react to the clicker as quickly as possible. In particular, a repeated contraction and relaxation strategy in the forearm and pull finger muscles should be developed for this reason (Ertan et al., 2003, 2005a, Soylu et al., 2006). That is why archery shooting can be considered to be a highly demanding task, which may also be one of the reasons that the N1 amplitude is higher when the archer achieves to hit the centre of the target.

Another possible explanation is the archer's high visual attention while shooting. It could be considered that when the archers reached high visual attention, the clicker's sound may plausibly be an irrelevant stimulus. Kramer and colleagues (1995) reported that mental workload leads to higher N1 amplitude; moreover, they argued that N1 amplitude could be used as an indicator of mental workload. Considering that the high mental workload consumes limited resources of attention (Mun et al., 2017), it is likely that possible high mental workload could be responsible for low N1 amplitude during missed shots.

There is some evidence for a task- or attention-induced stimulus-nonspecific increase in the excitability of some neuronal populations contributing to the N1 deflection. This increase causes the N1 amplitude to any input, relevant or irrelevant, to be larger when the subject is engaged in a specific task rather than relaxing, and larger when performing a more

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involved task rather than a less involved one. However, none of these findings exemplifies the performance as archery does because "performance" means the speed of the response (Reaction Time paradigm) in earlier studies, not the outcome of the performance. Ertan and colleagues (1996) researched archers to measure the effect of reaction time on the scores on the target. They have concluded that there was no correlation between the hits on the target and the reaction times of the participant.

We concluded that the fall of the clicker in archery shooting elicits an N1 response with larger amplitude for successful shots than unsuccessful ones, which can be explained by the highly motivated and attentive state of the archer, by the timing uncertainty of the clicker's fall, by the mental workload, and by the fact that the response is not solely to the clicker's sound but also to the tactile and visual stimuli created when it falls. A significant increase in response was observed when the archer hits the centre of the target. We were, however, unable to determine a significant difference between successful and unsuccessful shots in terms of N1 latency and/or P2 amplitude and latency as a response to the fall of the clicker. It is recommended that archers and their coaches receive regular support using biofeedback methods to evaluate their psychological states just before and/or after the fall of the clicker.

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