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# Smart Headgear for Assessment of Auditory Response Reaction Time of Professional and Amateur Kendokas †

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**Abstract:** In Kendo, the ability to execute a technique within the shortest time is essential for winning. The purpose of this study was to utilise an in-house developed automatic headgear-scoring sensor with a buzzer to determine the auditory response reaction time (ARRT) of professional (PK) and amateur (AK) Kendo practitioners. ARRT is defined as the time required for a participant to hit a target after a buzzer is sounded. A total of 14 participants took part in this study. The participants were requested to hit the opponent's headgear target, which consisted of a pressure sensor, upon hearing the buzzer. The average reaction time of PK is 0.44 s, and for AK 0.58 s, with a significant difference between the two groups ($p < 0.0001$). The in-house developed automatic headgear-scoring sensor with buzzer can be utilised to assist a Kendo practitioner in training to shorten the response reaction time to improve competition performance.

**Keywords:** Kendo; Smart Kendo Headgear; auditory response reaction time; reaction time; movement time; tactile sensor

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## 1. Introduction

Kendo is a Japanese swordsmanship derived from the practice of the samurai and the practitioner is known as a Kendoka. Current kendo competition utilizes a bamboo sword (Shinai) in a three-point match (Sanbon-Shobu) between two practitioners in full armour (Bogu) [1]. The first person to score two points wins the game. According to the International Kendo Federation (FIK) rules, there are four targets with equal points, which are Men (head), Kote (wrist), Do (upper-torso) and Tsuki (thrust to the throat). The point (Ippon) is decided by three umpires (Shinpan) by raising colour flags (red or white) [2]. An Ippon must meet all the requirements laid out by the International Kendo Federation (FIK) called Yūkō Datotsu [2]. "Yūkō Datotsu is defined as the accurate strike or thrusting made onto Datotsu-bui of the opponent's Kendo-gu with Shinai at its Datotsu-bu in high spirit and correct posture, and correct angle of the blade (Hasuji) being followed by Zanshin (continued alertness)" [3]. The challenge of judging a point is usually set by the speed of the strikes when both Kendokas strike simultaneously, in which the time difference can be as little as 0.009 s [4]. The Kendoka can also reach the target within 0.10 s [5].

Men-Uchi (strike Men: strike to the top of head) is one of most important and common attacking motions in Kendo. It is the first target area that beginners practice on for the striking motion. Edo et al. [6] studied a series of kendo matches in Japan and reported that out of 801 attempted strikes, 378 were Men-Uchi. They also reported that out of 47 valid points in the study, 25 were Men-Uchi.

Tatsumi also reports a similar finding from his studies in the All Japan University Kendo Championships and the All Japan Kendo Championships. He reported that the most frequently appearing technique among valid strikes were Men strikes [7]. Thus, Men strikes (the most basic of all strike) are frequently used in kendo matches and account for a high proportion of valid strikes.

Ippon-Uchi-no-Waza (attacking at one's own timing when a clear target is available: Men, Kote, Do, or Tsuki) is the most frequently appearing technique among valid strikes in All Japan University Kendo Championships and the All Japan Kendo Championships [7]. It is important that Kendokas practice shortening the length of time from the moment in which they sense an opportunity to attack to the moment they strike (response reaction time). The main factor that contributes to a successful valid strike is for one's own striking movements to be faster than the opponent's defensive movements [8]. Therefore, most Kendokas practise the repetitive striking motion to try to reduce the length of time of the striking motion and improve accuracy.

In term of scoring sensors used in martial arts, there are several Olympic martial arts disciplines currently utilising automatic scoring sensors as part of the judgement. In fencing, electric scoring was first introduced in Olympic level to épée in 1936, to foil in 1956, and to sabre in 1988. The central unit of the scoring system is commonly known as "the box". In the simplest version, both fencers' weapons are connected to the box via long retractable cables. The box normally carries a set of lights to signal when a touch has been made [9]. In Taekwondo, electronic protector judgement system was first adopted in 2007 and later adopted in the 2012 London Olympic Games. Impact force sensors have been installed onto the body protector and headgear (Hogu) [10]. However, there no electronic scoring has been adopted in Kendo to date.

In our previous study, the Kendo Men automatic scoring sensor was developed by utilising a pressure sensor. A piezo-resistive polymer was tested for this purpose. Strike force and sensor conductance exhibited a clear linear relationship with the sensor with the cut-off level of 319 N and 78.5 μS between scoring and non-scoring strike impacts. At the selected cut off levels, the impact force data showed only 9.26% false scoring results [11].

Sensor technology has been used in many fields of martial arts in both training and competitions in the last two decades. Many researchers have utilised the sensor technology to assist practitioners to achieve perfect motion, which usually requires long hours of training. Chye and Nakajima have developed a game-based approach to learning martial arts for beginners using Kinect sensor similar to many controller-less sensors in the gaming industry such as Kinect Sports, Fighters Uncaged and Wii Sports Resort [12]. Sensors have also been installed directly onto martial arts equipment for training purposes. James et al. [13] from Griffith University have installed accelerometers onto a wooden sword to study the dynamics of a swing. Another study carried out by Jeong et al. [14] was utilising pressure sensors equipped on to a Shinai, used in Kendo, to measure grip power. The study focused on the pressure distribution between the left and right hand during normal stance and an attacking motion to assist the beginner in learning the correct hand placements in Kendo. Therefore, this research is aiming to develop sensor technology that can assist in point scoring judgements.

## 2. Material and Methods

A total of 14 Kendokas, seven Professional Kendokas (PK) and seven Amateur Kendokas (AK), participated during the experiment. The study was granted Ethics approval by the Swinburne University Human Ethics Committee (approval No. 2016/296). This study utilizes in-house developed sensor technology to measure the Auditory Response Reaction Time (ARRT) of Men strikes between PK and AK. The equipment setup included of one tactile sensor: a buzzer and a microcontroller. The pressure sensor was made of a flexible conductive piezo-resistive polymer (Velostat, 3M, Thief River Falls, MN, USA) and implemented on the top of the Men. The buzzer, with an average buzzer duration of 0.069 s, (KEYES, KY-012, ACTIVE BUZZER MODULE, Shenzhen, China) was used as an auditory signal to initiate the Men attack phase. The pressure sensors and the buzzer were connected to a microcontroller (Teensy 3.1, PJRC.COM LLC, Sherwood, OR, USA) which was programmed via the Arduino IDE to run at a sampling rate of 3000 Hz. The participants were requested to hit the opponent's Smart Headgear target, which consisted of a tactile sensor, upon hearing the buzzer. This process was repeated 10 times for each participant. Subsequently, the ARRT data, defined as the time required a participant to hit a target after a buzzer is sounded, were recorded continuously to the laptop for further analysis.

For each strike, the recorded voltage signals from the buzzer and the tactile sensor were plotted against time. The midpoint of the buzzer signal was taken as the initiation of the motion and the time difference between the midpoint of the buzzer signal and the impact on the tactile sensor were calculated (see Figure 1). The data were divided into two groups, one for AK and the other for PK. The 2 groups were compared using Mann–Whitney U test, as the data collected were not normally distributed.

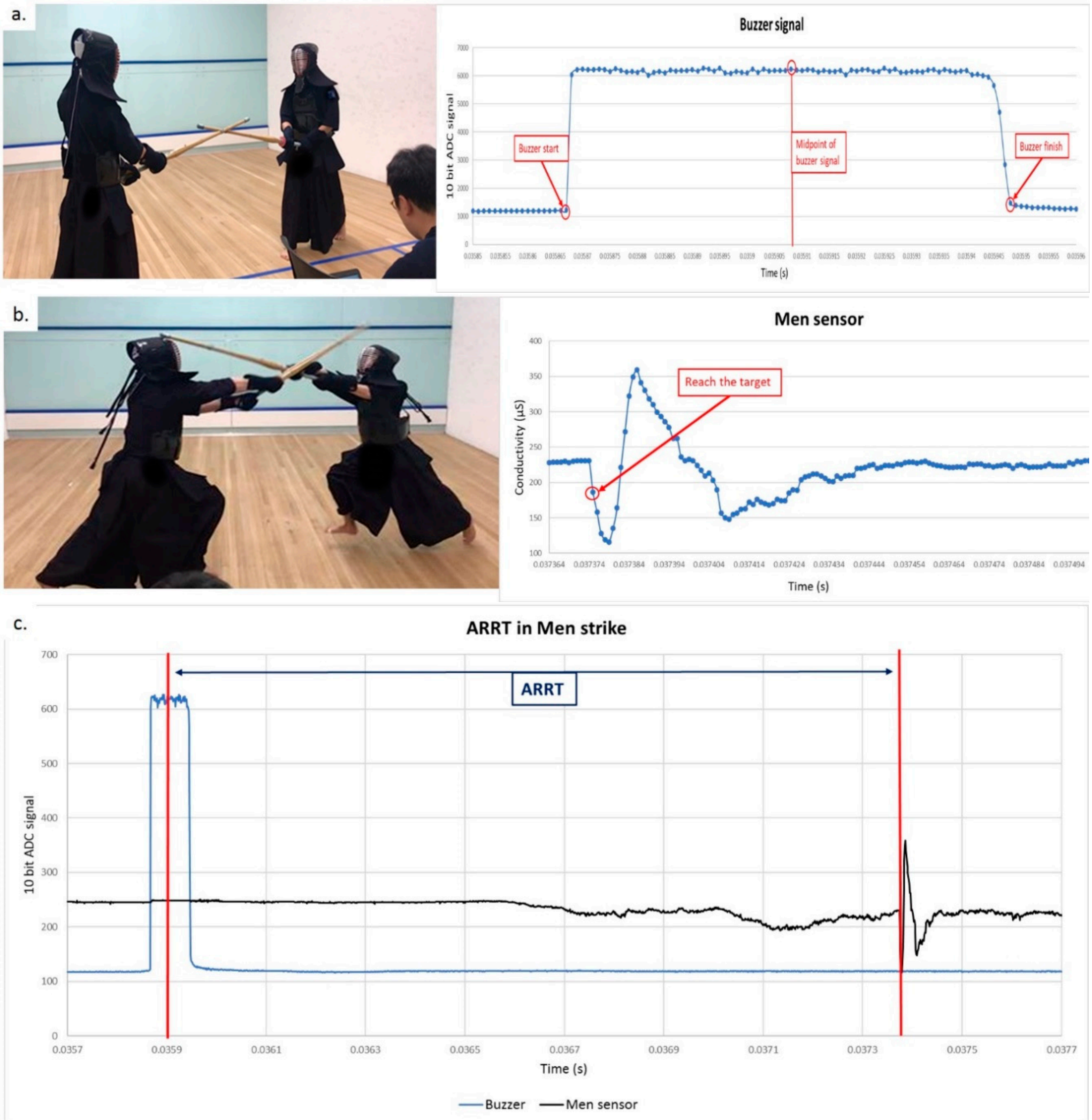


**Figure 1.** (**a**) Midpoint of buzzer signal; (**b**) the signal of Men sensor; (**c**) the example of auditory response reaction time (ARRT) in Men strike.

## 3. Results

Box-whisker plots in Figure 2 display the ARRT in Men strike of each of AK (Figure 2a) and PK (Figure 2b). ARRT in AK (Figure 2a) shows a higher variation in the individual ARRT (median range 0.41–0.84 s) in comparison to ARRT in PK (median range 0.41–0.54 s) (Figure 2b). The average ARRT of PK is 0.44 s (SD 0.09 s, range 0.40–0.54 s) and for AK, 0.58 s (SD 0.10 s, range 0.42–0.86 s) (see Figure

3a). The average of the standard deviation (Figure 3b) is lower in PK 0.09 s compared to AK 0.10 s. Figure 3c shows a significant difference between the two groups ($p < 0.0001$) when Mann–Whitney U test was used. The box whisker plots in Figure 3c summarize all the ARRT in Men strike in all AK and PK. The statistic results are summarized in Table 1. The in-house developed automatic headgear-scoring sensor with buzzer can be utilised to support the Kendo practitioner in training to shorten reaction time to improve competition performance.

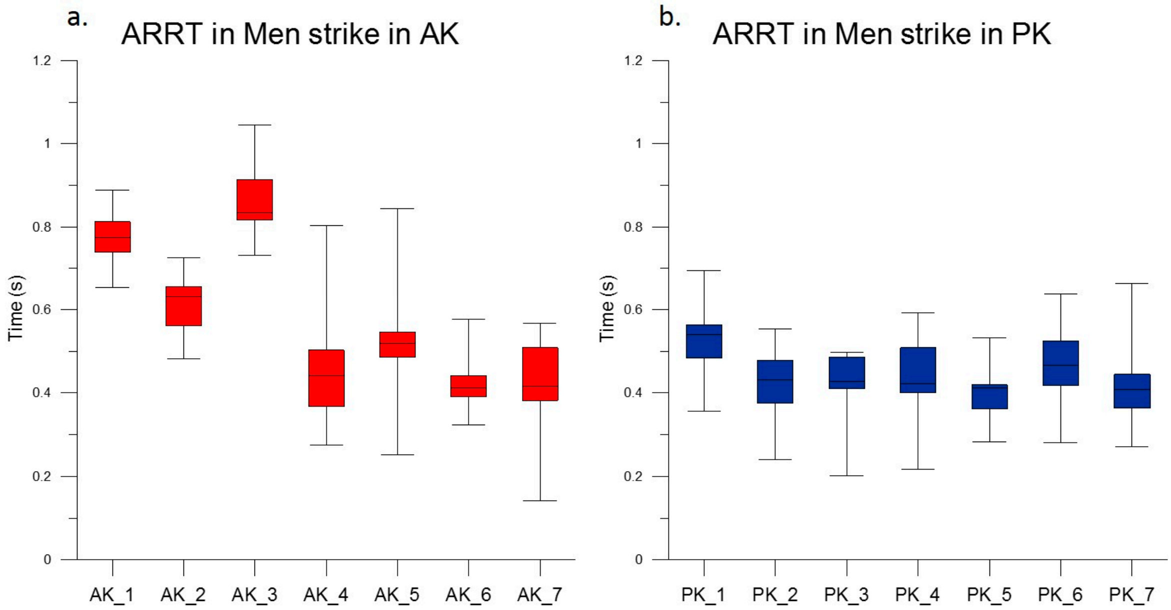


**Figure 2.** Comparison of the ARRT in Men strikes between amateur (AK) and professional (PK).

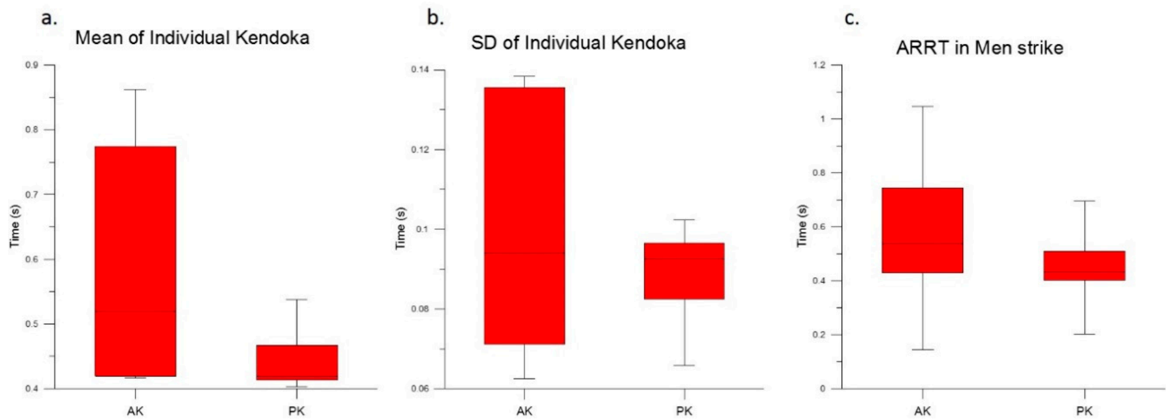


**Figure 3.** Comparison of data between AK and PK (**a**) mean ARRT of each individual over 10 strikes; (**b**) SD of ARRT of each individual over 10 strikes; (**c**) ARRT for all recorded strikes.

**Table 1.** The statistic for ARRT between PK and AK.

| **Average ARRT in Men Strike (s)** | | **Median ARRT in Men Strike (s)** | | **Standard Deviation ARRT in Men Strike (s)** | | **Minimum ARRT in Men Strike (s)** | | **Maximum ARRT in Men Strike (s)** | |
|---|---|---|---|---|---|---|---|---|---|
| AK | PK | AK | PK | AK | PK | AK | PK | AK | PK |
| 0.58 | 0.44 | 0.58 | 0.44 | 0.10 | 0.09 | 0.42 | 0.40 | 0.86 | 0.54 |

## 4. Discussions

The aim of this research was to develop sensor technology that can assist in point-scoring judgements. The findings show that the sensor is successfully developed in the ARRT of Kendoka hear the buzzer the time to reach the Men target. The average ARRT in PK (0.44 s) is statistically significantly lower than AK (0.58 s). The median and standard deviations are also lower in PK. The possible explanation for this is that the PK has a higher number of regular intensive training compared the AK. PK has five to six times per week approximately three to four hours per day and AK is up to three times per week approximately up to two hours per session. This may contribute to a shorter reaction time and/or shorter motion time. In this study, the in-house Smart headgear technology does not differentiate the reaction time and movement time. However, this low cost in-house Smart headgear technology is sufficient to assist Kendoka(s) in training to reduce the overall time to reach the target.

Further study could add another sensor to detect the body movement to differentiate between the reaction time and motion time. A visual signal can replace auditory signal to measure the visual reaction time of Kendoka(s).

This ARRT is the combination of Reaction Time (RT) and Movement Time (RT). However, this experiment does not differentiate between these two classifications. Future study will investigate the two classes RT and MT between different groups. Another further study will include visual response reaction time, as most Kendo techniques rely on visual observation and many techniques rely on body reaction when the target is visible.

As this study only involved the auditory response of the Kendoka, a future study can add to the development of a visual signal sensor to measure body movement to differentiate between the reaction time and motion time. More data from Kendoka(s) in different levels and genders must be collected to test the accuracy and provide feedback on the developed in-house Smart headgear sensor.

## 5. Conclusions

The in-house developed smart headgear was utilized in the assessment of the auditory response reaction time of professional and amateur Kendokas in Men Kendo motion (head-strike). The professional Kendoka had a significantly lower ARRT of Men cut upon hearing the buzzer sound compared to amateur Kendokas. This preliminary test showed that the low cost in-house Smart headgear technology is sufficient to assist Kendoka(s) in training to reduce the overall time taken to reach the target.

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**Conflicts of Interest:** The authors declare no conflict of interest.

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