VISUAL-PERCEPTUAL-MOTOR SKILLS OF ELITE SILAT ATHLETES WHEN RESPONDING TO VARIOUS COMBAT SITUATIONS THROUGH AN INTEGRATED STEREOSCOPIC SYSTEM

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Understanding the visual-perceptual-motor skill of an athlete can help optimize the periodization of a training plan. This study was designed to explore the visual-perceptual-motor skill of ten male elite Silat athlete when tasked to react to a set of projected video stimuli comprised of specific combat attack situations; side kicks, roundhouse kicks and crocodiles. A customized stereoscopic video system projected the stimuli in two- and three-dimensions with the latter being added with the aim of improving combat realism. This system synchronously recorded the gaze and movement behaviours of the participants when they responded to the combat situations. No differences in visual search behaviour, quiet eye and reaction time were found when tasked to respond between two- and three-dimensional videos, which may be due to the complexity of the stimulus. There was a significantly higher quantity and longer duration of fixations spent on the trunk of the opponent as compared to other areas of the body. Reaction time was also significantly different in the side kicks (slower responses) as compared to other attacks. Results from this study can pave way for future studies that seek to investigate how visual-perceptual-motor skill differs between expertise levels in the sport of Silat and serve as a basis for targeted coaching to enhance combat Silat performance.

KEYWORDS: PENCAK SILAT, VISUAL-PERCEPTUAL-MOTOR SKILL, VISUAL SEARCH BEHAVIOUR, QUIET EYE, REACTION TIME.

INTRODUCTION: Combat Pencak Silat is a class of sport martial arts which is practiced widely across Southeast Asia and is growing in popularity throughout the world. As the main objective of this sport is to avoid incoming physical attacks and landing strikes and takedowns to opponents to secure the win, a clear understanding of the visual-perceptual-motor skill (VPMS) of the athlete is crucial in shedding light on optimising a targeted training plan (Jackson & Farrow, 2005). This VPMS can be inferred from an athlete's visual search behaviour (VSB), quiet eye (QE) (Vickers, 2007) and movement i.e. reaction time (RT) during the task performance (Katsumata, 2007). To increase the ecological validity of reproducing the visual-perceptual demands of a game environment in a laboratory setting, stereoscopic video projections via the use of two-dimensional (2D) and three-dimensional (3D) videos of sport-specific situations to elicit and study skilled actions have been previously utilized (Lee, Bourke, Alderson, Lloyd, & Lay, 2010). The application of a 3D stereoscopic system in the sport setting has been limited therefore little is known about how additional depth cues may influence performance, particularly in martial arts. This present study aims to explore the VPMS of elite combat Silat athletes as they responded to various combat situations in 2D versus 3D conditions. Due to the differences offered by additional depth cues, it is hypothesized that (i) there would be differences in VPMS (VSB, QE and RT) when responding to 2D versus 3D conditions. Past research have reported that elite Soccer goalkeepers tend to fixate on the hips of their opponents when receiving a penalty kick because its position, whether opened or closed, would give away crucial information about the placement of the kick (Williams et al., 1994). Likewise, in the combat sport of Silat where strikes are thrown frequently both from the upper and lower limbs, we expect that (ii) Silat athletes would fixate on the central body segment; pelvis or trunk of their opponents regardless of attack.

METHODS: Ten male elite Silat athletes (experience = 11.9 ± 3.3 years) who have represented Singapore at regional and international competitions, were recruited for this study. All participants were informed as to the nature of the study and a written consent was obtained before undergoing one testing session at the Singapore Sport Institute Sport Biomechanics laboratory. The techniques used for the development of the 3D stereoscopic system followed as detailed previously in (Lee et al., 2010). For this study, an opponent was projected in multiple 2D and 3D scenarios, and in each scenario, this opponent executed specific attacks commonly employed by successful Silat athletes (Soo, 2018) which had required the lab-based participant to provide appropriate responses to. Two high-definition Panasonic HC-VXF-990 video cameras (Panasonic, Kadoma, Japan) planted on a customized dual-mount rig were used to film the opponents; two male individuals of different skill and experience level – elite and non-elite in combat Silat. There were 18 clips of each opponent in the respective 2D and 3D conditions which consisted of three unique single attacks; side kick, roundhouse kick and a crocodile (takedown), each performed three times with either the left or the right limb. In total, 72 combat situations in 2D and 3D were created, of which 36 were randomly selected for each participant (3 attacks X bilateral attacks X 2 dimensions X 3 successes) to minimise the effect of fatigue. Visual search behaviour; quantity, duration and location of the participants' fixations and QE were measured using a modified Dikablis Essential eye tracker (Ergoneers, Geretsried, Germany). The eye camera recorded the participants' points of gaze from the left eye, while the field camera captured their visual fields in the frontal plane. The participants' movements were captured using a 12-camera Vicon 3D MX system (VICON Motion Systems, Oxford, UK) sampling at 200 Hz. Prior to data collection, all participants were fitted with polarized glasses and a head-mounted eye tracker, synchronized using infrared timing gates along with a custom-built interface unit. In addition, 28 single retro-reflective markers were affixed to the participants' trunk, pelvis, upper and lower limbs.

Familiarization trials were then administered before proceeding with eye tracker calibration. After which, a pre-randomised playlist was selected, and protocol instructions were re-iterated before the test commenced. Participants performed an evasion followed by a counterattack from an on-guard position (deemed appropriate response) approximately one leg's length away from a large stereoscopic screen, in response to an attack from a projected opponent in 2D and 3D. Cutting the timing gates triggered the projection of the virtual opponent. In each trial, a virtual opponent executed single attacks on the viewing participant using one of three various combat techniques performed bilaterally (left or right limb) under both 2D and 3D conditions. The combat situations for which the participants had responded inappropriately were replayed at the end of the initial 36 trials. The test ceased when three successful trials per attack, performed bilaterally and in 2D and 3D conditions, were recorded. Visual search behaviour was determined based on the (i) average number of fixations per area of interest (AOI) and (ii) average duration of fixations per AOI as a percentage of the total duration of fixations in the period of interest. Quiet eye was defined as the final fixation on a specific location before the initiation of an evasion and was determined by looking at the QE duration and the pelvic shift of the participant. The total duration of fixations and QE duration for each participant were normalised to 100% and coded based on 11 AOIs which had covered the fixation locations both on and off the opponent's body (Lee et al., 2013). Nine AOIs were located on the opponent's body (head, left shoulder, right shoulder, left arm, right arm, trunk, pelvis, left leg, right leg). Fixations which fell outside of the opponent's body were coded as "other", while missing data due to blinking were coded as "occluded". Reaction time data was obtained through the analysis of 3D motion data. Time taken to initiate an evasion was measured from the first obvious frame of opponent's attack initiation to the first measurable lateral shift of the participants' mid-pelvis in the mediolateral plane when its position had exceeded five standard deviations from the mean. Statistical analysis was performed using the IBM® SPSS® Statistics 22 software (IBM Corporation, Armonk, NY, USA) where initially a series of three-way repeated measures analysis of variance (ANOVA; Attack X AOI X Dimension) was conducted to investigate the differences in VSB, QE and RT across various regions, between 2D to 3D conditions. As no significant differences in the aforementioned variables were found, a separate three-way ANOVA (Attack X AOI X Dimension) was performed to investigate any differences in VSB, QE and RT when both data from 2D and 3D conditions were combined. Alpha values were set at <*.05* and the Sidak post-hoc comparison was used to analyze any significant main interaction effects when applicable.

RESULTS: No significant differences were found in the total number of fixations (p = .202), total duration of fixations (p = .878), QE duration (p = .469) and RT (p = .480) between 2D and 3D conditions. Therefore, when tasked to respond to video projections, 2D videos were found to be as effective as 3D videos. Table 1. compares the average number of fixations per AOI, average duration of fixations per AOI as a percentage of the total duration of fixations in the period of interest and QE duration averaged across participants coded based on 11 AOIs. The average number of fixations and the percentage of fixations on the trunk of the opponent were significantly higher in general as compared to the other AOIs (p < .05). Quiet eye location was on the trunk of the opponent for a significant amount of time as compared to the other AOIs (p < .05).

Table 1. Summary of all participants' VSB and QE duration averaged across 11 AOIs.

	Number of fixations	Percentage of fixations (%)	QE duration (%)
Head	0.35 ± 0.1*	9.7 + 5.3*	6.4 + 3.4*
Left shoulder	0.14 ± 0.0*	1.2 + 0.4*	0.8 + 0.4*
Right shoulder	0.13 ± 0.1*	1.3 + 0.9*	0.5 + 0.5*
Left arm	0.27 ± 0.1*	8.5 + 4.6*	6.9 + 3.9*
Right arm	0.13 ± 0.0*	2.0 + 0.7*	1.5 + 0.6*
Trunk	0.87 ± 0.2	38.1 + 9.1	32.1 + 8.3
Pelvis	0.47 ± 0.1	11.2 + 4.6*	7.0 + 2.9*
Left leg	0.28 ± 0.1*	7.8 + 5.0*	6.6 + 4.8
Right leg	0.32 ± 0.1	11.2 + 6.8	9.5 + 6.0
Other	0.05 ± 0.0*	0.2 + 0.1*	0.0 + 0.0*
Occluded	0.04 ± 0.0*	0.1 + 0.1*	0.0 + 0.0*

Note: * indicates significant differences from the trunk. p < .05.

Figure 1. compares RT between the three bilateral attacks. Reaction time when responding to the left side kick were significantly slower than the right roundhouse kick (p = .003), left roundhouse kick (p = .002) and right and left crocodile (p < .05).

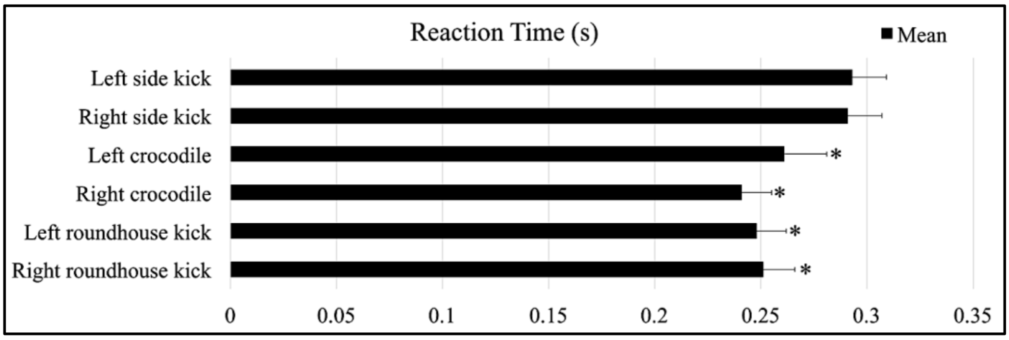

Figure 1. Reaction time between all three bilateral attacks. * indicates significant differences from the left side kick. p < .05.

DISCUSSION & CONCLUSION: This study investigated the VPMS and RT of elite Silat athletes when responding to Silat specific attacks, between 2D and 3D conditions. The total number and percentage of fixations, QE onset, offset, duration and RT were not significantly different between 2D and 3D conditions. This could be due to the low complexity of the projected attacks and the simplicity of the evasive response required, whereby sufficient information could have been obtained from 2D videos alone and any additional depth cues offered from the 3D video would not have been necessary (Theeuwes, Atchley, & Kramer, 1998). Future studies may consider increasing the attentional demands of the task at hand by increasing the complexity of the visual scenarios presented via the inclusion of feints with

attacks to elicit more pronounced differences between 2D and 3D conditions. It was found that a significantly higher quantity and longer duration of fixations were spent on the trunk of the opponent. Likewise, QE locations were generally found to be on the trunk which is in line with our hypothesis. As there was a higher quantity of fixations and a bigger proportion of time spent fixating on the trunk, it is likely that the participants were maintaining their gaze on the central location of the opponent's body which acts as a visual pivot from where they can pick up pertinent information to create appropriate responses (A. Piras & Vickers, 2011) and be aware of situational probabilities (Milazzo, Farrow, Ruffault, & Fournier, 2016). This visual pivot strategy employed by the athletes serves as a more cost-effective strategy as it widens the covert area of attention and reduces the information acquired by overt attention (A. Piras & Vickers, 2011). The participants had responded significantly differently to the side kicks (left and right were < 0.35 s) as compared to other attacks whereby the RT was significantly slower in the former than the other attacks. Nonetheless, the average execution time of a side kick was found to be 0.39 s (Wąsik, 2011), suggesting that the participants would still have managed to avoid incoming side kicks. It is possible that the upper body and pelvic movements leading up to the roundhouse kick and crocodile (takedown) provided more obvious visual cues than the side kick, therefore the participants were only able to respond to the side kick after the opponent's feet has left the ground.
Despite not having found any significant differences in VPMS between 2D and 3D conditions, the integrated 3D stereoscopic system is a viable solution to overcome the difficulties associated with quantifying visual-perceptual skills and motor skills interdependently. This system can assess VPMS, while preserving a high level of ecological validity as compared to the traditional methods (Jackson & Farrow, 2005) by offering quasi game-realistic stimulus presentations. By having a baseline VPMS of elite athletes in Silat, coaches would now have a better indicator of their athletes' level of expertise and form as a guideline when coaching sub-elite athletes i.e. to focus the gaze on the trunk. Results from this study can pave the way for future studies that seek to investigate how VPMS differs between expertise levels in the sport of Silat and serve as a basis for targeted coaching to enhance combat Silat performance.

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