READ AND REACT: EFFECTS OF TASK COMPLEXITY ON MOTOR SKILL EXECUTION

Lucy Parrington[1,2], Clare MacMahon[3] and Kevin Ball[1,2]

[1] Institute of Sport, Exercise and Active Living (ISEAL), Victoria University, Melbourne, Victoria, Australia
[2] College of Sport and Exercise Science, Victoria University, Melbourne, Victoria Australia
[3] School of Biomedical and Health Sciences, Faculty of Health, Arts and Design, Swinburne University, Hawthorn, Victoria, Australia

Performance in team sports requires players to both observe their game environment and proceed with technical skill. This case study evaluated if changing the complexity of a perceptual-motor task caused technical performance changes. Kinematic data were collected and analysed for 34 handballs across four levels of complexity using visual and auditory stimuli (simple-response, choice response, choice response with distractor, choice response with cross modality distractor). Kinematic differences were found between the simple response and choice response task for six out of 10 parameters. Although differences occurred, the effect of distractor stimuli on handball kinematics was unclear. The cognitive complexity of a task may affect technical performance and therefore has implications for biomechanical testing environments.

KEYWORDS: kinematics, handball, Australian football, distractor, perceptual-motor

INTRODUCTION: In elite team sports such as Australian football, successful execution of skills requires a balance of technical skill and cognitive abilities. Starkes, Cullen and MacMahon (2004) suggested that performance may be facilitated or constrained by the constant interaction between perceptual-cognitive and perceptual-motor pathways. For example, a player with expert technical ability will be limited during game performance if they lack the ability to efficiently gather and process information.

Over the past decade there has been a drive toward increasing testing fidelity (Starkes et al., 2004). Findings such as increased decision making accuracy and enhanced anticipation have been found to occur when movement responses have been included in the testing protocol (Bruce, Farrow, Raynor & Mann, 2012; Mann, Abernethy, & Farrow, 2010). Of studies using a coupled approach, however, most researchers have only provided information on the cognitive aspects of performance, offering only the general outcome as a measure of technical skill. Furthermore, the main limitation of studies in the area of motor learning is the lack of detailed technical information collected from the participant(s). Typically, studies have placed focus on the cognitive process, rather than the mechanical process. Few have examined whether a change in motor execution is elicited by changes in cognitive task.

Biomechanics can contribute to the discipline of motor learning in sport by providing a means to analyse the mechanics of the movement with greater precision (Buttfield, Ball, & MacMahon, 2009). An example of this is provided by Panchuk, Davids, Sakadjian, MacMahon and Parrington (2013) who analysed both kinematics and eye movement for changes in a visual-perceptual task. Results included reduced skill performance and changes in visual tracking when advanced perceptual information was removed. Additionally, through kinematic analysis, delayed hand movement initiation, faster maximum hand velocity, greater maximum grip aperture and shorter time to both maximum hand velocity and maximum grip aperture were found in the absence of advanced perceptual information.

As demonstrated by the results of Panchuk et al. (2012), analyzing the kinematics of elite player movement in a coupled perception-action experimental setting may provide more information on the mechanisms underlying skilled performance. The aims of this study were to assess whether kinematic differences occurred increases in task difficulty (increased passing options and distractions), and whether kinematic differences occur when players respond to auditory stimulus versus visual stimulus.

The Australian football handball was chosen as the motor skill as Australian footballers are often required to perform handball passes under contested situations (Dawson et al., 2004), requiring efficient decision making and successful motor-skill execution.

METHOD: One elite male (23 yrs, 84 kg, 1.85 m) participant was selected from a professional Australian Football League club based on the length of time of participation (5 years, approx. 2.5 – 3 hours skills based training per week). The participant was undertaking in-season training and free from injury at the time of testing. The University Human Research Ethics Committee approved all methods.
Apparatus: Five bulls-eye targets were spaced equally apart in a star like formation, which formed a 360-degree movement space. The centre circle (0.2 m diameter) of the target was composed illuminating panel able to interchange between blue and red emissions of equal luminosity. Directly underneath the centre circle was removed to expose a 6-inch speaker, used to emit the auditory stimuli. All targets had the ability to trigger either visual or auditory stimuli individually or simultaneously with other target emissions. Target stimuli were triggered using a specifically designed control interface (Labview, National Instruments Corporation, Austin, TX, USA). Pilot procedures were conducted to determine the time interval where participants were unable to discriminate the difference between signal onsets. Auditory signals, recorded into Mixcraft acoustic software (Acoustica, Inc., Oakhurst, CA, USA) were digitally manipulated to have the same onset time and decibel level.
Protocol: The participant wore team training shorts, singlet and running shoes and was fitted with movement tracking marker clusters as previously described prior to the onset of the testing protocol (Parrington, Ball, & MacMahon, 2012). Anatomical markers were virtually stored to determine joint centres at the shoulder, elbow, wrist and the centre of the hand. A standardised warm up including handballs on the preferred arm was completed to help the participant become accustomed to the testing environment. Participants were required to complete 34 preferred limb handballs across four different testing complexity levels (Table 1).

Table 1: Breakdown of task

Complexity level	Trials	Task requirement
1 Simple response (1-SR)	8	One stimulus is emitted from one target only. Handball to target on stimulus signal. Auditory and visual signals tested.
2 Choice response (2-CR)	10	One stimulus is emitted from one of five targets. Handball to the target that emits the stimulus. Auditory and visual signals tested.
3 Choice response with distractor same modality (3-CRD)	10	Two stimuli are emitted from two of the five targets. One valid and one invalid (distractor). Handball to the target that emits the valid stimulus. Both stimuli are of the same modality (e.g. valid visual signal vs. invalid visual signal)
4 Choice response with distractor different modality (4-CRDX)	6	Two stimuli are emitted from two of the five targets. One valid and one invalid (distractor). Handball to the target that emits the valid stimulus. Stimuli are of differing modalities (e.g. valid auditory signal vs. invalid visual signal)

A short break was provided between each testing level during which the specific task requirements were reaffirmed with the participant. The participant was instructed to pick up the ball from the ground and handball toward the target centre emitting the valid stimulus using 'game-intensity'. Testing was completed using a Sherrin football (69kPa, Russell Corporation, Victoria, Australia).
Data Collection and Analysis: Three-dimensional data were collected using Optotrak Certus at 100 Hz (Northern Digital Inc., Ontario, Canada) and analysed in Visual3D (C-Motion, Inc., Maryland, USA). Raw data were smoothed using a low-pass Butterworth filter (7 Hz, Parrington et al., 2012). Maxima and minima data were used to calculate range of motion

(ROM). All other parameters were collected at the instant prior to ball contact. Accuracy scores were manually recorded based on a 3-2-1 rating, per 0.2 m deviation from the centre and reviewed using video footage. Statistical analysis (p < 0.05) was conducted in SPSS 20.0. Data were assessed using analysis of variance through linear modelling procedures with task complexity and stimulus modality entered as fixed factors.

RESULTS: Significant differences were found for hand speed and path, shoulder speed, shoulder ROM, shoulder angular velocity and support hand position (Table 2). Multiple comparisons for significant findings are given in Table 3.

Table 2 Kinematic Parameters

Parameter	Definition	ANOVA result
Accuracy	Absolute target accuracy based on Bulls-eye target	$F(3,33) = 0.400$, $p > 0.05$
Hand speed	Linear velocity of the hand at ball contact	$F(3,33) = 8.740$, $p < 0.001$
Hand path	Direction of the hand with respect to the line of the centre of the target at ball contact	$F(3,33) = 5.693$, $p = 0.003$
Shoulder speed	Linear velocity of the striking arm shoulder at ball contact	$F(3,33) = 6.160$, $p = 0.003$
Shoulder path	Direction of the shoulder with respect to the line of the centre of the target at ball contact	$F(3,33) = 1.648$, $p > 0.05$
Shoulder ROM	Range of shoulder flexion between maximum backswing and ball contact	$F(3,31) = 3.333$, $p = 0.032$
Elbow ROM	Range of elbow flexion between maximum backswing and ball contact	$F(3,31) = 2.152$, $p > 0.05$
Shoulder angular velocity	The maximum angular velocity associated with shoulder flexion	$F(3,33) = 6.037$ $p = 0.002$
Elbow angular velocity	The maximum angular velocity associated with elbow flexion	$F(3,30) = 0.882$, $p > 0.05$
Support hand position	The vertical distance between the support hand and the pelvis	$F(3,25) = 6.292$ $p = 0.002$

Table 3 Multiple comparisons for significant findings

		Hand speed		Hand path		Shoulder speed	
Level		Mean diff	P	Mean diff	P	Mean diff	P
1-SR	2-CR	-0.50	**0.01**	-4.57	**0.01**	-0.26	**0.01**
	3-CRD	0.36	0.06	-6.97	**<0.001**	0.06	0.54
	4-CRDX	-0.10	0.65	-2.24	0.27	-0.23	**0.04**
2-CR	3-CRD	0.86	**<0.001**	-2.40	0.15	0.32	**<0.001**
	4-CRDX	0.41	**0.04**	2.33	0.22	0.03	0.74
3-CRD	4-CRDX	-0.45	**0.03**	4.73	**0.02**	-0.29	**0.01**

		Shoulder ROM		Shoulder angular velocity		Support hand position	
Level		Mean diff	P	Mean diff	P	Mean diff	P
1-SR	2-CR	-10.60	**0.01**	-69.60	**<0.001**	-0.04	**0.01**
	3-CRD	-5.30	0.17	-71.00	**<0.001**	-0.06	**<0.001**
	4-CRDX	-10.53	**0.02**	-73.00	**<0.001**	-0.08	**<0.001**
2-CR	3-CRD	5.30	0.10	-1.40	0.94	-0.01	0.46
	4-CRDX	0.07	0.99	-3.40	0.87	-0.03	0.10
3-CRD	4-CRDX	-5.23	0.15	-2.00	0.92	-0.02	0.30

DISCUSSION: Successful skill performance can be facilitated or constrained by the interaction of between perceptual-cognitive and perceptual-motor pathways (Starkes et al., 2004). Most research conducted in this area has been approached from a cognitive perspective. In contrast, this case study looks at the changes in technical performance that may occur due to changes in cognitive complexity in a task.

Results provide evidence of differences in handball technique used between the simple response task and choice response task, with faster hand speed, shoulder speed and shoulder angular velocity occurring as well as a less direct hand path, greater shoulder ROM and the support hand being held closer to the pelvis. Based on Hick's Law (Hick, 1952), the reaction time taken to attend to a choice response task is longer than a simple response task. Therefore, the increased linear and angular speed differences between 1-SR and 2-CR may have been a counter measure to decrease the total response time taken.

Differences between 2-CR and 3-CRD indicate that the player may have had slightly more difficulty in this task, requiring a slower hand and shoulder speed. Although the difference is not significant between 2-CR and 3-CRD, the hand path is less direct, which has been implicated as effecting handballing accuracy (Parrington et al., 2012).
The increase in both hand and shoulder speed between the two distraction tasks 3-CDR and 4-CRDX may indicate the propensity toward handballing quicker if the decision component of the task has taken longer. Comparatively, if taken with the significantly more direct hand path in 4-CRDX, could indicate that distractors of the opposite modality formed an easier task than the choice response with distractors of the same modality.
Although the mean values were not significantly different between 2-CR, 3-CRD and 4-CRDX, shoulder angular velocity increased while the ball was held nearer to the body for an increase in complexity level. It is of interest to see whether this type of trend is demonstrated in other players. One of the main limitations of this study was the use of an active marker system, which prevents the ability to track the ball.

CONCLUSION: This case study explored the effects of cognitive complexity on technical skill. Although significant results were found across a number of parameters, only shoulder angular velocity and support hand position values moved in the direction expected. Findings suggest that changes in the perceptual complexity of a task can affect the technical performance of motor skill execution. This has implications for biomechanical research as it suggests different testing environments and task requirements may affect research findings. Additionally, findings ad rationale to the use of a multidisciplinary approach when assessing task performance and suggests further research should be conducted, which evaluates the effects of perceptual-cognitive complexity on motor performance.

REFERENCES:

Bruce, L., Farrow, D., Raynor, A., & Mann, D. (2012). But I can't pass that far! The influence of motor skill on decision making. *Psychology of Sport and Exercise*, *13*(2), 152-161. doi: 10.1016/j.psychsport.2011.10.005

Buttfield, A., Ball, K., & MacMahon, C. (2009). The use of motor learning in biomechanics: a call for more collaboration. *International Journal of Sport Psychology, 40*(4)*,* 603-615.

Dawson, B., Hopkinson, R., Appleby, B., Stewart, G., & Roberts, C. (2004). Player movement patterns and game activities in the Australian Football League. *Journal of Science and Medicine in Sport*, *7*(3), 278-291. doi: 10.1016/S1440-2440(04)80023-9

Hick, W. E. (1952). On the rate of gain of information. *Quarterly Journal of Experimental Psychology, 4*(1), 11-26.

Mann, D. L., Abernethy, B., & Farrow, D. (2010). Action specificity increases anticipatory performance and the expert advantage in natural interceptive tasks. *Acta Psychologica, 135*(1), 17-23. doi: 10.1016/j.actpsy.2010.04.006

Panchuk, D., Davids, K., Sakadjian, A., MacMahon, C., & Parrington, L. (2013). Did you see that? Dissociating advanced visual information and ball flight constrains perception and action processes during one-handed catching. *Acta Psychologica*, *142*(3), 394-401. doi: 10.1016/j.actpsy.2013.01.014

Parrington, L., Ball, K., & MacMahon, C. (2012). Square to the target? Coaching cues and technical analysis of the Australian football handball. In E.J. Bradshaw, A. Burnett, & P.A. Hume (Eds.), *Proceedings from the 30th International Conference on Biomechanics in Sports* (pp. 158-161), Melbourne: Australian Catholic University

Starkes, J. L., Cullen, J., & MacMahon, C. (2004). A life-span model of the acquisition and retention of expert perceptual-motor performance. In A. M. Williams, & N. J. Hodges (Eds.), *Skill acquisition in sport: Research, theory and practice* (pp. 259-281). London: Routledge.

Acknowledgement

This study was made possible by the support of the Western Bulldogs Football Club. The authors would like to acknowledge Robert Stokes for his technical assistance in developing the stimulus emitting targets.