

**Interpersonal and extrapersonal coordination in high-  
performance rowing**

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BEd

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## ATTESTATION OF AUTHORSHIP

I hereby declare that this submission is my own work and that, to the best of my knowledge and belief, it contains no material previously published or written by another person nor material which to a substantial extent has been accepted for the award of any other degree or diploma of a university or other institution of higher learning, except where due acknowledgement is made in the acknowledgements.

Chapters Two to Five of this thesis represent separate papers that are either published or have been submitted to peer-reviewed journals for consideration for publication. My contribution and the contribution by the various co-authors to each of these papers are outlined in the “candidate contributions to co-authored papers” table. All co-authors have approved the inclusion of the joint work in this PhD thesis.



Sarah-Kate Millar

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## CANDIDATE CONTRIBUTIONS TO CO-AUTHORED PAPERS

<p><b>Chapter 2</b></p> <p>Millar, S. K., Oldham, A. R. H., and Renshaw, I. (2013). Interpersonal, Intrapersonal, Extrapersonal? Qualitatively Investigating Coordinative Couplings between Rowers in Olympic Sculling. <i>Nonlinear Dynamics, Psychology and Life Sciences</i>, 17, 425-443.</p>	<p>Millar 75%, Oldham 20%, Renshaw 5%</p>
<p><b>Chapter 3</b></p> <p>Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hopkins, W. Athlete and coach agreement: Identifying successful rowing performance. <i>International Journal of Sports Science &amp; Coaching</i>. In press.</p>	<p>Millar 80%, Oldham 10%, Renshaw 5%, Hopkins 5%</p>
<p><b>Chapter 4</b></p> <p>Millar, S. K., Oldham, A. R. H., and Renshaw, I. Establishing extrapersonal coordination; in expert level single sculling. <i>Human Movement Science</i>. Under review.</p>	<p>Millar 80%, Oldham 15%, Renshaw 5%</p>
<p><b>Chapter 5</b></p> <p>Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hume, P. Evaluating catch efficiency measures in rowing; testing biomechanical variables from the PowerLine boat instrumentation system against rowers perceptions of on-water stroke success. <i>Sports Biomechanics</i>. Under review.</p>	<p>Millar 80%, Hume 10%, Oldham 5%, Renshaw 5%</p>



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## **ETHICAL APPROVAL**

Ethical approval was granted by Auckland University of Technology Ethics Committee (AUTEC).

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Chapters 2-5:

- 09/104 Establishing the key timing and coordination points required for successful performances in multiple rower boats. Approved 19 May 2009.
- 11/161 What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed. Approved 21 July 2011.

# RESEARCH OUTPUTS RESULTING FROM THIS DOCTORAL THESIS

## PRE-REVIEWED JOURNAL PUBLICATIONS

1. Millar, S. K., Oldham, A. R. H., and Renshaw, I. (2012). Interpersonal coupling in rowing: the mediating role of the environment. *Journal of Sport and Exercise Psychology*, 34(Supp), 110-111.
2. Millar, S. K., Oldham, A. R. H., and Renshaw, I. (2013). Interpersonal, Intrapersonal, Extrapersonal? Qualitatively Investigating Coordinative Couplings between Rowers in Olympic Sculling. *Nonlinear Dynamics, Psychology and Life Sciences*, 17, 425-443.
3. Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hopkins, W. Athlete and coach agreement: Identifying successful rowing performance. *International Journal of Sports Science & Coaching*. In press.
4. Millar, S. K., Oldham, A. R. H., and Renshaw, I. Velocity matching and interception; the catching problem in rowing. *Human Movement Science*. Under review.
5. Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hume, P. Evaluating catch measures in rowing; testing establishing models against rowers perceptions of on-water success. *Sports Biomechanics*. Under review.

## PEER REVIEWED CONFERENCE PRESENTATIONS

- 1) Millar, S-K. (2012). *Interpersonal coupling in rowing: the mediating role of the environment*. Poster presentation at the North American Society of Sport Psychology and Physical Activity Conference (NASPSPA), Hawaii, USA.

## CONFERENCE PRESENTATIONS

- 1) Millar, S-K. (2012). *Interpersonal coupling in rowing: the mediating role of the environment*. Paper presented at the Australasian Skill Acquisition Research Group meeting, Melbourne, Australia.
- 2) Millar, S-K. (2013). *Extrapersonal coordination; Expert level single sculling*. Paper presented at the Australasian Skill Acquisition Research Group meeting, Sydney, Australia.

## INVITED PRESENTATIONS

- 1) Millar, S-K. (May, 2012). *Understanding key perceptual variables utilised in successful rowing*. Rowing New Zealand, Lake Karapiro.
- 2) Millar, S-K. (October, 2012) *Coach and Rower agreement*. Rowing New Zealand, Auckland.
- 3) Millar, S-K. (November, 2012). *Athlete and coach agreement*. Greater Auckland Coaching Unit research evening, Auckland.
- 4) Millar, S-K. (November, 2013). *Interpersonal & Extrapersonal Coordination In High-Performance Rowing*. University of Cincinnati; Center for Cognition, Perception and Action.
- 5) Millar, S-K. (December, 2013). *Sport and Human Movement in New Zealand: Trends and Current Issues*. Rohde Island College.

- 6) Millar, S-K. (December, 2013). *Velocity matching in rowing*. Brown University; Virtual Environment Navigation Laboratory (VENlab).
  
- 7) Millar, S-K. (December, 2013). *Interpersonal & Extrapersonal Coordination In High-Performance Rowing*. College of Holly Cross; Psychology Department.

## TERMINOLOGY

Bow (seat)	The sculler or rower seated closest to the bow
Catch position	The furthest reach point of the oar handle towards the stern of the boat; also known as minimum oar angle
Double scull	A boat designed for two scullers each using two oars
Drive phase	The propulsive phase of the stroke where the blades are moving from the catch position to the finish position and are in the water
Ergometer	A land based rowing machine– with a single central handle that does not differentiate between stroke and bow sides
Finish position	The furthest reach point of the oar handle towards the bow of the boat
Foot-stretcher	An angled plate in the boat that the rowing shoes are attached to
Gate	See “oarlock”
Longitudinal axis	The line along the middle of the boat from the bow to the stern
Oar	Entirety of the oar shaft and blade, positioned through the oarlock and used by the rower to propel the boat
Oarlock	Sometimes termed “gate”, this is the point of attachment of the oar(s) to the boat
Pair	Two-oared sweep boat with two rowers
Pin	The oarlock(s) rotate around the pin fixed in the rigger(s)
Recovery phase	The non-propulsive phase of the stroke where the blades are moving from the finish position to the catch position and are not in the water
Sculling	A class of rowing where a rower holds an oar in each hand
Single scull	A boat designed for one sculler using two oars
Slip	Either at the catch or finish, “slip” refers to oar excursion angles that do not contribute to propulsion whilst the blades are moving from the catch position to the finish position
Square-off	Position where the oar is perpendicular to the longitudinal axis of the boat and the oar angle is zero
Stern	The front of the boat when moving in its intended direction of travel
Stroke (seat)	The rower or sculler seated closest to the stern
Sweep rowing	A class of rowing where each rower holds one oar

## **ABSTRACT**

Rowing presents a unique perception–action problem. The challenge is not for rowers to try to couple their actions together, as thought by many, but rather, it is to coordinate their actions with that of the boat. This thesis reveals how high-performance rowers exploit visual regulation in a novel way to achieve interpersonal coordination, by timing their movements with the water and the boat. The objective of this thesis was to expand knowledge regarding the role of timing in high-performance rowing and understand the perceptually driven solutions in successful performance.

Previous literature surrounding timing in rowing has been predominately biomechanical and has focused on the rower or the boat in isolation from each other. In contrast, this thesis takes an ecological dynamics perspective, viewing the rower’s relationship with his/her environment as one system. In this approach, emergent behaviours are tightly coupled with perceptual information perceived by the rower.

Involving experts in making judgements about performance in order to understand the rower–boat relationship was a fundamental approach adopted in this thesis. This idea is based on the premise that methods adopted by expert coaches have emerged through constant testing in the harsh world of high-performance sport; meaning that only successful ideas that have stood the test of time are utilised in the performance environment. An initial qualitative study with expert-level rowers and coaches was undertaken to establish the importance of timing and how it was achieved. The original findings from this study shaped the remainder of the thesis. Specifically, expert rowers and coaches stated that while interpersonal coordination between rowers is crucial for performance, it is not achieved by direct coupling to each other’s actions as generally thought, but indirectly through individual rowers timing their movements with invariant information provided by the boat and water. The connection with the boat and water was termed by experts “rowing with the boat”. Hence, if both rowers can row in time with the boat, then they will be in time with each other; but they do not actively seek to row in time with each other. An additional important finding from this study was that experts also identified the catch section of the rowing stroke as strongly influential on timing success.

This thesis used an innovative method to distinguish successful strokes from less successful ones. While performing in the boat, rowers identified nominated strokes as either *Yes* or *No* strokes. This was based on their perceptions during the performance environment about the speed of the boat and the success of the catch. This technique proved to be an accurate method for measuring performance variables, and *Yes* nominated strokes were found to reflect that the boat was travelling more quickly/better than it was when rowers identified *No* strokes.

Quantifying what experts termed “rowing with the boat” was an important outcome from this thesis, where it was found that rowers coupled their speed to that of the boat on the recovery section of the rowing stroke. Specifically, rowers were able to cancel out the rate of change in boat velocity by varying their approach speed towards the catch. This strategy allowed little or no change in the rate of optic flow, and thus maintained perceptual constancy. In order to achieve this coupling, high-performance rowers made early adjustments in their oar angle speed on the recovery to slow them down. Consequently, these early adjustments allowed more time for continuous perception–action coupling between rower and environment, rather than making last-minute adjustments close to the catch, as was the case in *No* strokes.

The concluding section of this thesis focused on understanding what a successful catch is in rowing. An alternative method of measuring the catch was established; based on rowers’ qualitative comments, and this was compared with three existing biomechanical measures. The alternative catch measure had a larger impact on performance than the previously established measures. This result highlighted again the value in using rower-based judgements about performance; as what is good and what is fast might not always be the same thing in rowing where water conditions can vary.

In summary, the thesis has established that timing in rowing is crucial for success and this is determined by the relationship between the rower and the boat. Temporal coordination between the rower and the boat emerged as a result of the rowers’ movements, which was coupled to specifying perceptual information. Therefore, successful timing is a result of continuous coupling of perception and action via attunement to key perceptual information.

# CHAPTER 1

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## INTRODUCTION



*Figure 1.1: Winning Men's double, London Olympics.*

*How does the shortest crew in the race come from behind to win Olympic Gold? "What makes a rowing boat go fast?" is the central question to this thesis.*

## Background

Rowing presents an uncommon perception–action problem, as success requires careful temporal interception between an unsighted oar under the control of the rower and the water, which is a uniquely unstable target. To be successful, rowers not only have to undertake a complex, multi-articular coordination task and organise their limbs to be in the right place at the right time, but also must attune these movements to complement a highly dynamic and fluid environment. Additionally, rowing events where there is more than one person in the boat require coordination of his/her movements with others. All of these actions need to be performed at or near maximal physiological output when racing and training (Bechard, Nolte, Kedgley, & Jenkyn, 2009). This level of complexity separates rowing from all but a few other sports, and requires a skill that can take years to master. A key to developing expertise as a rower is to accurately attune to perceptual information from the water and boat, which provides rowers with key timing information to enable success. In essence, successful rowing is a nested coordination problem between the rower, the boat and the environment.

The ultimate goal of rowing is to race a set distance (usually 2000 m) in the shortest time possible, and consequently a rower's ability to maximise the average velocity of the boat is critical to performance. Therefore, this does not make it a kinetic problem of stored potential energy during training alone, but rather a problem of how to expend it with the greatest efficiency. Since humans only have a fixed energy capacity, maximising average velocity of the boat will require energy-efficient solutions to be established between the rower(s) and boat.

To date, most efforts to understand successful rowing performance have been tightly constrained to gathering boat speed data from international rowing regattas (e.g. Smith & Hopkins, 2012; Smith & Hopkins, 2011); physical (e.g. Doyle, Lyttle, & Elliott, 2010) and anthropometric (Barrett & Manning, 2004; Kerr, Ross, Norton, Hume, Kagawa, & Ackland, 2007) dimensions of rowers; plus land-based physiological testing on ergometers (Dawson, Lockwood, Wilson, & Freeman, 1998; Lamb, 1989; Ritchie, 2008) or in the gymnasium (Lawton, Cronin, & McGuigan, 2013). Consequently, while these studies have provided specific physiological parameters and descriptive performance data, which are specific to those isolated settings, this tight focus has left a number of unanswered questions about successful on-water

performance. In particular, there is a lack of integration between research findings (e.g. from the studies noted above) and on-water performance; which is a problem often left for the coach to solve.

A few studies have begun to explore the relationship between the rowers' physical abilities and their on-water performance. For example, a study by Coker (2010) demonstrated that while stroke power and stroke length are important predictors of rowing performance, they hold no direct relationship with boat velocity. This invites questions about the identity of key variables, which have the greatest influence on rowing performance at the highest level. A starting point suggested by Baudouin and Hawkins (2004) is to consider the timing between the rower and boat, as they believed that poor coordination would create torque about the shell and slow the boat down by increasing drag. Although these authors did not go on to define good coordination, or identify the part(s) of the stroke that had the most impact on performance, their suggestion warrants further exploration. Consequently, how timing in rowing is achieved appears to be an original phenomenon yet to be understood.

## **Methodology**

### ***Theoretical approach***

Ecological dynamics is the theoretical view adopted in this thesis, which fuses key concepts from dynamic systems and ecological psychology (Araujo, Davids, & Hristovski, 2006; Vilar, Araújo, Davids, & Button, 2012). Ecological dynamics seeks to understand phenomena at the ecological scale of analysis, and has a specific focus on the self-organising relationship between the individual and his/her environment. Therefore, this thesis aims to identify environmental constraints that underpin this relationship in an applied high-performance rowing setting. In pursuing an understanding of timing in rowing, key concepts from dynamic system theory will be reflected upon; specifically, synergetics (Haken, 1988; Jirsa, Fink, Foo, & Kelso, 2000; Kelso, 1994; Riley, Richardson, Shockley, & Ramenzoni, 2011) and self-organising, energy-efficient solutions to tasks. Also to be considered is dynamic systems research by Schmidt and colleagues (e.g. Marsh, Richardson, Baron, & Schmidt, 2006; Richardson, Marsh, Isenhower, Goodman, & Schmidt, 2007; Schmidt, O'Brien, & Sysko, 1999), who studied how

behaviour changes and settles into a steady state. Considering timing from a purely dynamic system viewpoint would not fully explain how behaviour is emergent and based on the individual–environment relationship, a problem better viewed from an ecological dynamics perspective (Araujo et al., 2006; Schollhorn, Hegen, & Davids, 2012; Seifert, Button, & Davids, 2012).

An ecological dynamics perspective uses tools of dynamic systems theory in order to understand the emergent actor-environment interaction at a broad ecological-scale view (Araujo et al., 2006). A related approach to ecological dynamics is behavioural dynamics (Fajen & Warren, 2007; Warren & Fajen, 2008). Behavioural dynamics can be considered an operationalisation view of Gibson's work and places emphasis on the individual as opposed to the entire system. Therefore behavioural dynamics may be considered to include elements limited to the strict perception-action dyad. At times this thesis will examine both ecological and behavioural dynamics. While these approaches are similar in terms of their focus on the emerging interaction between the actor and the environment, they are not interchangeable approaches. Ecological dynamics is the overarching theoretical focus of this thesis, specifically because of its emphasis on representative design, whereas, behavioural dynamics does not lead itself to this application. Behavioural dynamics is explored in one chapter of this thesis because as a model, it suggests the actor is mechanically coupled through forces applied through sensory fields that are structured by the environment (Fajen & Warren, 2007; Warren & Fajen, 2008). It is this mechanical coupling that has not been previously highlighted in an ecological dynamics perspective, and consequently is explored in chapter four. Therefore, an ecological dynamics perspective that focuses on representative design drives the theoretical focus of successful timing in rowing in this thesis.

## ***Methods***

Considering the perceptually driven problem of timing in rowing and how success depends on the tightly coupled relationship between the rower and his/her environment necessitates an understanding of previous methods for studying perceptual skills. Although the study of perceptual skills has a long history of being examined in multiple settings (e.g. Fajen, Riley, &

Turvey, 2009; Hodges & Williams, 2012; Leonard, 2007; Salter, Wishart, Lee, & Simon, 2004; Temprado & Laurent, 1999), unfortunately these studies have tended to be laboratory-based and use video techniques (see van der Kamp, van Doorn, & Masters, 2009 for criticisms of these approaches). Consequently, these approaches have tended to de-couple the process of perception and action (Williams, Davids, & Williams, 1999) by solely focusing on the “perception” and neglecting “action”. In an attempt to remedy this, some study designs – known as *in situ* studies – have carefully considered ecological validity and endeavoured to study perception and action in natural performance settings. Carefully considering the experimental setting by sampling the environment to ensure it is representative of the performance setting is a central concept of Brunswik’s (1956) work. Brunswik believed that researchers should look at the interrelations between the performer and his/her environment, calling for representative task design when working with studies of perception and action to ensure that experiments represent the behavioural setting to which the results are intended to be generalised (Araujo, Davids, & Passos, 2007; Davids, Button, Araujo, Renshaw, & Hristovski, 2006; Pinder, Davids, & Renshaw, 2011). Essential to achieving this goal is maintaining all key information sources, so that the perception–action link is not de-coupled. For example, key information sources in rowing include the boat and natural water conditions. This Brunswikian view is central to the methodological approaches undertaken in this thesis, which is one of the biggest challenges, but also a major highlight. Since the actions a performer takes are a direct consequence of what he/she perceives in the environment (Davids, Button, & Bennett, 2008), examining tasks in the natural performance environment is important to ensure the accurate depiction of key processes in adaptive behaviour, such as perception and action. While actions taken will be specific and vary according to the individual (Araujo et al., 2006; Seifert & Davids, 2012), it is how performers adjust their behaviour as a result of environmental information to which they attune that is of most interest in this thesis. Therefore an ecological dynamics approach that deals with real time mutuality of the performer and his/her environment underpins the methods adopted in each chapter.

## ***Literature***

Early approaches to perception and action (e.g. Gibson, 1986) looked at an individual's ability to pick up information relevant to action. The key idea from Gibson's (1986) work was that movement generates information, which in turn supports further movements, leading to a cyclical relationship between information and movement. Gibson's (1986) theory of direct perception emphasised how actions depend on the perception of substances in the environment e.g. objects like oars, or surfaces like water. The properties of these substances provided opportunities for action or affordances (Gibson, 1966, 1986) and emerge from the dynamic organism–environment relationship. Gibson also specified the concept of invariants and how they provide information for action. Therefore the ability of performers to detect change in the environment provides them opportunities for action.

It has been argued that skilful athletes are able to execute actions from a continuously changing environment (Savelsbergh, Williams, Ward, & Kamp, 2002) and are able to attune to key affordance information (Fajen et al., 2009) more quickly than less skilful athletes. Their success is driven by their ability to perceive information from the dynamic performer–environment context, facilitating emergent behaviours. How skilful athletes adapt to emergent information is based on a self-organising process, and the ability to modify actions in response to perceptual information generated from the surrounding environment (Kelso, 1995). Behaviours that emerge from a continually changing environment correspond well to an ecological dynamics approach, where reciprocal changes influence each other. As noted under theoretical approach, this view contrasts with the behavioural dynamics model, which is examined in chapter four; in that it is focused on the emerging state of both the environment and performer, which is shaped by the constraints on the whole system. For example, when a rower takes an action in response to information from the environment, this will impact on the movement of the boat, which will afford new information that the rower will again respond to. In contrast, behavioural dynamics is concerned about how interaction with the environment affects the emergent behaviour of the performer. For example, it considers how optic flow information can influence the actions of the rowers, rather than taking a broad ecological-scale view of how the performer–environment relationship continuously emerges. This continuous adjustment observes rules of dynamics and settles on stable and energy-efficient solutions (Jirsa et al.,

2000; Kelso, 1995), and obeys the law of energetics. As performers spend more time in similar environments, they tend to adapt their movements to meet the task demands by using the most energy-efficient coordination pattern, resulting in the lowest amount of effort (Sparrow & Newell, 1998). Since athletes' energy resources are not finite, this energy-conservation strategy would appear to make sense.

Establishing energy-conserving solutions to coordinative tasks was first recognised by Kelso (1984) through his intrapersonal coordination finger-tapping task. The task involved performers tapping their fingers in-phase with each other, but as the speed of movements increased, performers were found to change to an oscillating anti-phase timing sequence. This switch to anti-phase coordination was found to be a more energy-saving state than in-phase tapping (Kelso, 1984). A time-based sport like rowing is an example of where energy conservation is required in order to cover a set distance in the fastest time possible. The athlete at the start of a race could be considered like a battery; he/she has a set amount of energy to use over the race and he/she has to find the most energy-conserving method to race a set distance as quickly as possible (Martindale & Robertson, 1984). The solution is not to make a bigger battery (i.e. increase physical capacity), which has been shown not to work, and is costly to run, as it would result in greater mass in the boat and create more drag on the boat (Baudouin & Hawkins, 2002; Findlay & Turnock, 2010; Purdy, Potrac, & Jones, 2008). Instead, skilfully timed movements, which are energy efficient, are required (e.g. Figure 1.1, where the crew with shorter strokes has won). Achieving this economical solution will be dependent on developing an effective interaction between the individual, the boat and the environment. This interaction will dynamically emerge and depend on the ability of the athlete, water and boat constraints and the task demands at the time. Consequently, an ecological dynamics position allows an effective way of understanding coordination between an individual and his/her performance environment (e.g. Kelso, 1994; Kelso, 2002; Richardson, Marsh, & Schmidt, 2005), as energy-efficient solutions are sought.

Economical solutions to interpersonal coordination tasks, where one individual coordinates his/her movements with the behaviour of another, have also been established (e.g. Schmidt & Richardson, 2008). Interpersonal coordination movements are considered as self-organising and a perceptually driven process, rather than the product of pure mechanics (e.g. Bernieri &

Rosenthal, 1991). Recent research in this area (e.g. Richardson et al., 2007; Richardson et al., 2005; Schmidt, Fitzpatrick, Caron, & Mergeche, 2011; Schmidt & Richardson, 2008) has demonstrated via a variety of unnatural and simple cooperative tasks that interpersonal coordination is strengthened or supported by visual perception of movement. Specifically, in two-person interpersonal coordination tasks, visual information about each other is fundamental to achieving a stronger interpersonal coupling. For example, when two people visually interact while swinging a hand-held pendulum, a coupled-oscillator dynamic emerges (Richardson et al., 2005). This experience of an oscillating system using informational linkages (i.e. vision of each other) and adjusting to match the demands of the other system is not confined to people; it can also occur across the media of mechanical linkages (Schmidt et al., 2011; Schöner, Haken, & Kelso, 1986). For example, in a demonstration where two metronomes were set at different frequencies and placed on a board on top of two soda cans, over time the metronomes self-organised to share the same oscillating frequency (Schmidt et al., 2011). While vision was not the medium to allow coordination to occur, vibration and force through the shared board allowed interpersonal coordination to be achieved. Therefore, the role of perception is as a conduit between the two, which facilitates energy flow and the emergence of a low energy state. Consequently, interpersonal coordination couplings can be formed via a wide range of media.

Previous studies have shown that intra and interpersonal coordination occurs in a range of contexts; however, there has been limited exploration out of the laboratory, or in sporting performance environments. This has been partly due to the difficult nature of experimental control of performance-based studies (Araujo et al., 2007; Kudo, Park, Kay, & Turvey, 2006; Morice, Francois, Jacobs, & Montagne, 2010). An alternative method to studying intra and interpersonal coordination sees multiple variables measured *in situ*; however, this approach has its own problems. In particular, the challenge for researchers is to be clear about which variables from a multivariate problem to test, as many variables in a performance environment are uncontrollable and so are problematic to test. Consequently, understanding how coordination is achieved or controlled in rowing is challenging. One solution to the problem of which variables to study, without moving through a time-consuming process of testing one variable at a time, is to ask experts.

Experts have been found to play a powerful role in providing experiential knowledge about what factors underpin top-level performance (e.g. Greenwood, Davids, & Renshaw, 2012). In terms of understanding interceptive actions, asking expert performers what perceptual information they attune to can provide valuable knowledge regarding successful performances. Incorporating expert knowledge fits within an ecological approach of not separating individuals from their environments in order to study them. One way to achieve this is through a mimetic approach (Dawkins, 1989), which describes how successful ideas and knowledge are reproduced over time. These ideas or images are based on shared information and task solutions, which have been communicated between experts over time, tested and therefore will guide their actions. In a high-performance sporting environment, practice and competition provide a suitable evolutionary environment from which only the fittest (most useful) knowledge units will emerge, as these are the successful ones. On the whole, sports science research has tended to neglect this rich information source, due to the difficulties involved in measuring and validating it (Sparkes, 2002). By understanding the experiential knowledge of expert performers such as athletes and coaches, and in particular (in this thesis) the competitively selected memes they possess about successful rowing, our understanding of performance can be enhanced.

## Thesis Chapters

### *Structure of the thesis*

This thesis (see Figure 1.2) includes four chapters reporting results from data analyses that culminate in an overall discussion. Chapters 2 to 5 have either been accepted for publication or have been submitted for publication in journals. Therefore each chapter is presented as it was worded for the respective journal; consequently, there is some repetition in the introduction and methods between the chapters. References are not included at the end of each chapter; rather, as required by Auckland University of Technology (AUT) for thesis submission, an overall reference list for the entire thesis is set out at the end of the final chapter.

Chapter 6 is split into three sections. The first will explain key theoretical implications and increases in knowledge that can be attributed to this thesis and reflects on the thesis methodology. Second, in keeping with the philosophy of this thesis, of not separating the performer from his/her environment, a summary of the four studies completed will be presented in the format of a report, with an applied research focus back to key stakeholders (i.e. national sporting body – Rowing New Zealand). The concluding section will cover limitations and delimitations placed on the research along with suggestions for future investigations.

In summary, **this thesis will explain how relatively “underpowered” rowers can make boats go fast.**

## INTERPERSONAL AND EXTRAPERSONAL COORDINATION IN HIGH-PERFORMANCE ROWING

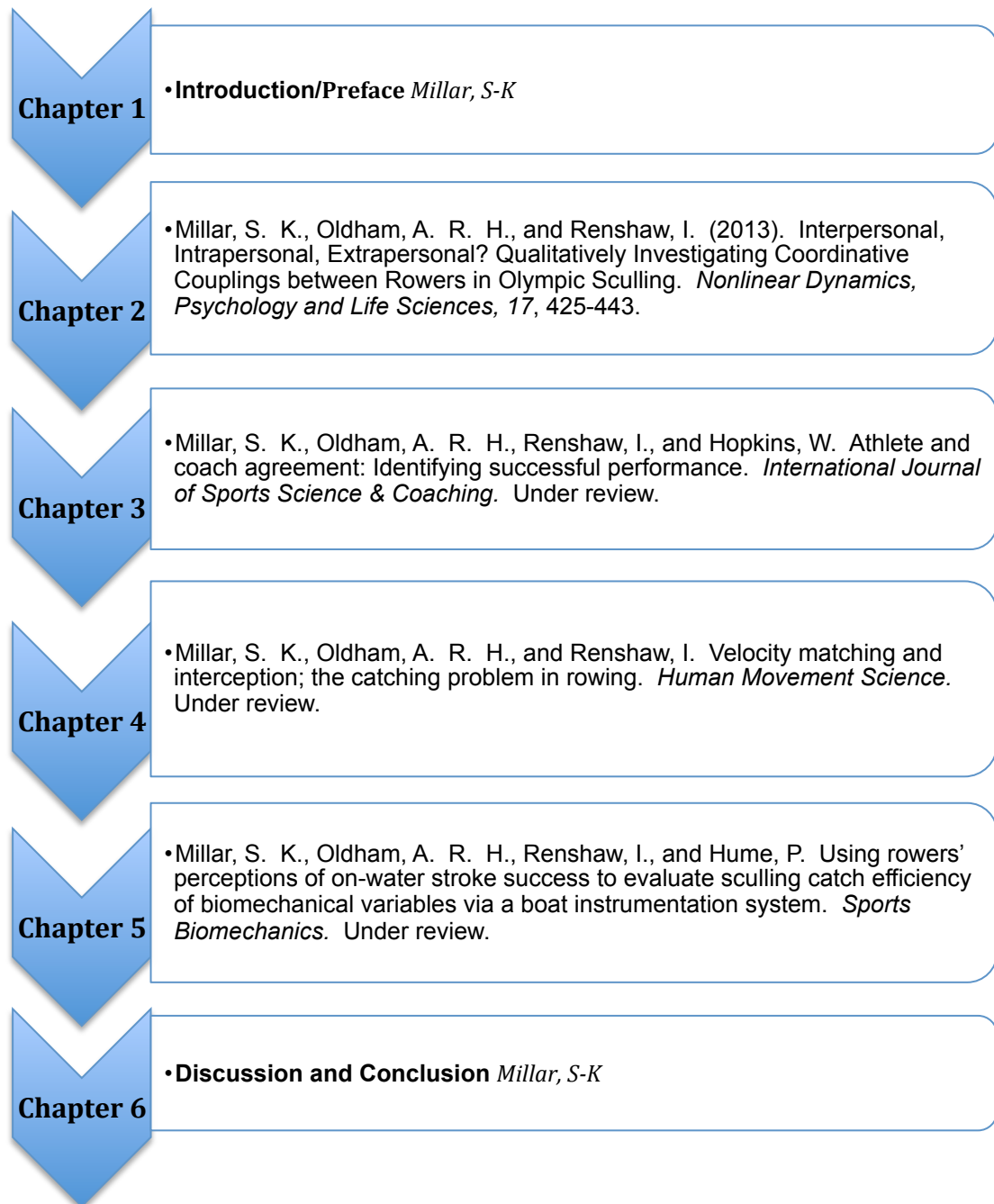


Figure 1.2: Overview of thesis chapter flow

## **Chapter 2**

Interviewing expert rowers and coaches has the potential to provide invaluable information about key determinants for success in rowing. Consequently, interviews with expert performers of two-person rowing boats will form the basis of Chapter 2. There are two distinctive subject groups: one group constitutes four Olympic-level rowing coaches; and the other group nine Olympic and World Championship level rowers. These performers have been chosen because of the level of knowledge and ideas retained by experts, as a consequence of prolonged, high-level practice and competition (Dawkins, 1989; Greenwood et al., 2012). What perceptual information experts attune to is dependent on their particular performance environment. For example, in rowing, the coach is a passive observer, yet plays a powerful role directing the performance environment (Hodges & Franks, 2002; Kidman & Hanrahan, 2011). In contrast, rowers are physically performing, and spend a lot of time training by themselves (Nolte, 2011), which consequently requires them to make regular adjustments to their technique based on what they perceive to be correct. These two unique viewpoints can offer invaluable insight into the same phenomenon, and precipitated the decision to interview both expert groups.

Key questions that will be addressed in Chapter 2 are:

- 1) What are the key determinants for success in expert rowing boats?
- 2) What is the role of timing in expert rowing performance?
- 3) How is perceptual information used to control and develop timing?

It should be made clear that adopting a grounded theory approach has been rejected in this study. This is because of the researcher's previous experience as an international rowing coach, which means that it would be unrealistic to expect that she could avoid imposing a prior structure on the data (Krippendorff, 2004; Krippendorff, 2013). However, the researcher's background allows a deeper understanding of the topic and richer questions to be asked. For this reason, an inductive content analysis approach has been used, allowing for expert knowledge to be part of the process, which suited the nature of the research questions in this thesis. The use of an inductive content analysis is a valuable technique for making inference from text content and in particular coding schemes or categories or definitions from answers to

open-ended questions in interviews (Biddle, Markland, Gilbourne, Chatzisarantis, & Sparkes, 2001; Krane, Andersen, & Streaan, 1997; Krippendorff, 2013; Patton, 2002). In addition, this qualitative method has been shown to be well suited for deriving new theory, which Chapter 2 aims to achieve, rather than verifying existing theory (Krippendorff, 2013; Schamber, 2000).

The qualitative approach chosen in Chapter 2 allows rich information to emerge about what determines success in two-person rowing boats, and how timing is achieved and controlled. In particular, three key findings are established. First, timing is considered to have an important impact on performance; second, timing is between each rower and the boat, rather than directly between the rowers themselves; and third, the timing of when the oar goes in the water at the catch is the most important part of the stroke. The following quote from an Olympic rower illustrates how important timing is: *“I think timing is everything basically; but it is more important to be in time with the boat, than anything else.”*

Based on the key findings from the qualitative study with expert performers, the direction for the rest of this thesis was established. In particular, it focuses on how successful timing is underpinned by a relationship between the rower and the boat and what perceptual information supports timing at the catch.

### **Chapter 3**

A key decision for this thesis was determining how many rowers in a boat (i.e. the size of boat) to study when investigating the main aspects of coordination and timing, as identified by the experts. The decision to move away from two-person boats and examine single scull boats (Figure 1.3) is based on two considerations. Primarily, if timing in rowing is about the relationship between the rower and the boat, then other rowers' movements need initially to be excluded, in order to consider the rowing action in isolation. Traditional interpersonal coordination has been studied between two people using information linkages (e.g. vision of each other while on a rocking chair) or when two objects share a common base of support and interact mechanically (e.g. a board on top of two soda cans with different set metronome speeds that couple together (Schmidt et al., 2011)); however, no studies have examined interpersonal coordination with a combination of both informational and mechanical linkages. The qualitative data in Chapter 2 will indicate that experts use visual information from the water,

and boat performance information from forces applied to the boat, in order to coordinate their movements with the boat. This implies that interpersonal coordination in high-performance rowing is achieved through the use of information and mechanical linkages, rather than just informational linkages as in the case of other forms of interpersonal coordination (i.e. Richardson et al., 2007; Richardson et al., 2005; Schmidt et al., 2011). Therefore, Chapter 3 (and the remaining chapters of this thesis) will examine the relationship between one rower in a single rowing boat, in order to understand how timing is achieved and what makes a boat go fast. Furthermore, it will focus on the catch section of the rowing stroke, based on the qualitative comments from experts.



*Figure 1.3: Focus shift from two-person boats to singles and examining the catch*

In order to understand how behaviour emerges from the relationship between the rower and his/her environment (specifically the boat and water), this thesis focuses on rowers in their performance-training environment. The emphasis remains on the use of expert knowledge, but through the use of performance-based direct perception or 'in-action' judgements while rowers are performing, instead of just indirect perception-based interviews. Performance-based or magnitude estimation of judgements is a common scaling method used in psychophysics (Gescheider, 1988) which aims to make qualitative comparisons between particular instances of perception that relate to a particular physical stimulus intensity. In Chapter 3, the performer makes judgements about performance that are grounded on the information–movement couplings he/she is making at the time (i.e. attempting to preserve the perception–action link).

It could be argued that requiring the rower to make a conscious perceptual judgement while he/she is performing could break the perception–action link and cause skill failure (Masters,

Law, & Maxwell, 2002). It was felt this would not occur here, as the athletes were not required to provide knowledge about performance, but rather to make a simple Yes or No judgement. Furthermore, the judgement only required the rower to focus on the movement outcome, which involved a lower-level neural processing (Davids et al., 2008) than consciously processing explicit knowledge, through describing the movement. Asking athletes to make a simple judgement appears to fit with the literature, as experts hold higher levels of knowledge that can be verbalised than novices do (Maxwell, Masters, & Eves, 2000) and, consequently, it is expected that they have this knowledge. This expectation is also based on a qualitative study with expert rowers who expressed confidence in knowing whether a performance was successful or not (Millar, Oldham, & Renshaw, 2013).

Requiring performance judgements from participants has a history in research on other sporting domains. For example, Borg (1970) developed a successful psychophysical scale to allow “subjective” measurement of physiological responses to exercise. It is thought that the benefit of using psychophysical studies with physically stressful activities is that they can be used to perceive important information that is hard to measure physiologically from the performer or physically from the performance environment (Gamberale, 1972). One example of information of this kind is information that the performer is able to attune to and act on based on his/her direct interaction with the environment. In addition to measurement scales related to physical activity, perceptual information measures have been developed. For example, Fajen, Diaz and Cramer (2011) demonstrated that performers are knowledgeable with respect to their own locomotor capabilities. In particular, they are more knowledgeable about their own action performance capabilities when they are moving than when they are stationary (Fajen et al., 2011), as their movements link to the information they perceive from the environment. Therefore, perceptual information measures are employed in Chapter 3, where expert rowers are asked to make qualitative judgements about performance.

A focus of Chapter 3 will be to broaden the understanding of the qualitative statements in Chapter 2, where expert coaches claim they know when a performance *looks* “right” and rowers know when it *feels* “right”. This invites the question, do they agree? Specific key questions that will be addressed in Chapter 3 are:

- 1) Does what “feels right” for rowers, correspond with what “looks right” for coaches?
- 2) Are phases of rowing that feel and/or look right the fastest?

Chapter 3 will establish that coaches and rowers are able to identify when the boat is travelling faster or slower. Interestingly, when the performance is marginally faster or slower, they disagree, and generally the rowers are more accurate about the performance than their coach. This is the first known study to compare the judgement of athletes and coaches with an external performance measure like boat speed. Such a comparison demonstrates the value of athlete knowledge about his/her own performance environment and highlights the importance of coaches working with athletes to exploit this knowledge.

#### ***Chapter 4***

A key concept that experts identify in Chapter 2 is that successful catch timing is based on a dynamic and emerging relationship between the rower and the boat. Specifically this relationship is called “rowing with the boat”, and it will be the focus of Chapter 4. A performer–environment interaction like this is comparable to Warren’s (2006) concept of behavioural dynamics. This term highlights the adaptive relationship between the performer and his/her environment, which is coupled by perceptual information (Warren, 2006). It emphasises the role of constant concurrent information directing behavioural change in the performer, and is specific to the individual and the environment at the time. For example, in rowing, both the boat movement and what is perceived are emergent, as are the related affordances. This is similar to the environment–performer interaction in catching fly balls (Fajen et al., 2011; Kistemaker, Faber, & Beek, 2009; Michaels & Oudejans, 1992) or moving through traffic (e.g. Louveton, Montagne, Berthelon, & Bootsma, 2012). Specifically in rowing, this would correspond to the speed the rower is travelling at coupled to the speed of the boat. Chapter 4 will consider the following key questions:

- 1) Do top-level rowers match their speed to the boat on the approach to a successful catch?
- 2) Is success characterised by coupling movements to visual information as reflected in boat speed?
- 3) Is a successful catch economical and efficient?

Results from Chapter 4 will reveal that skilful rowers do couple their actions with the speed of the boat; this finding supports the experts' description of "rowing with the boat". This tight coupling between rower and boat speed is maintained until just prior to the point of interception (the insertion of the oar in the water). The rowers achieved this coupling by making adjustments in the speed of their oar angle movements earlier before the catch, resulting in maintenance of a faster boat speed. This demonstrates a real-world example of the behavioural dynamics model (Warren, 2006) and how the rowers' behaviour emerges from their interaction with the environment and their own movements. From an ecological dynamics perspective, it also reveals how changes in water or boat information provide affordances for action, and once the rower makes an action, this changes the boat–water–rower relationship and thus prompts further emerging behaviours.

## **Chapter 5**

Chapter 5 will focus on comparing *maximum boat pitch velocity* with established biomechanical measures of catch efficiency, and determining which has the biggest impact on performance. In order to make this decision, rowers are required to distinguish successful from less successful strokes while performing in a single scull. Contemporary research about what defines a successful catch in rowing is predominately based in biomechanics literature (e.g. Coker, 2010; Kleshnev, 2002a; Kleshnev & Baker, 2007; Richardson, 2005), and is related to the rower reaching particular forces early. Experts (in Chapter 2) highlight the movement of the stern of the boat (which is part of the boat they can see in front of them) as a key information source for a successful catch. The rowers called this "picking up the boat" which refers to the change of boat pitch, or vertical displacement of the bow of the boat in centimetres (Sinclair, Greene, & Smith, 2009) during the drive phase of the stroke. When the stern of the boat is down in the water and the bow (front end) is up, there is a large drag force on the boat. In an attempt to quantify the qualitative comments, an alternative catch method to those in the literature is established for use in Chapter 5; this is *maximum boat pitch velocity*. This approach measures the movement of the stern, or the pitching of the boat, and it is designed to see how quickly the stern (of the boat) lifts up, after the catch. It is anticipated that the timing of this event is a direct relationship between the rower and the boat, and a quicker time to *maximum boat pitch velocity*

would reduce the drag on the boat by returning the boat to a horizontal position quickly. Specifically, key questions that will be addressed in Chapter 5 are:

- 1) Do successful strokes, as identified by rowers, correspond with boat performance data?
- 2) Which approach to measuring catch efficiency best reflects rowers' judgements of successful performance?

Results in Chapter 5 will establish that the best catch measure for predicting performance is *maximum boat pitch velocity*. This alternative method is found to be useful for quantifying the catch to those previously established from boat instrumentation systems. In addition, successful strokes correspond to a quicker *maximum boat pitch velocity* for successful (Yes) strokes, than for less successful (No) ones. As speed is an essential indicator of performance, an assessment of speed is also analysed, from which it is found that Yes strokes maintain a faster boat speed during the drive phase of the stroke than No strokes do.

**In summary, Chapters 2, 3, 4 and 5 will create the following new knowledge:**

- 1) Interpersonal coordination has commonly been achieved via a direct visual link between organisms, which in rowing cannot be achieved. This thesis shows how rowers exploit visual regulation in a novel way to achieve interpersonal coordination. Rowers achieve this by matching the speed of their movements with the speed of the boat during the recovery section of the stroke. Therefore, interpersonal coordination between the rower and the boat appears to be visually regulated.
- 2) Achieving interpersonal coordination has been demonstrated via informational linkages between people, or mechanical linkages between objects. This thesis will present a real-world example of achieving interpersonal coordination via a combination of mechanical and informational linkages. Visual regulation about the speed of the water is the informational linkage, and the change in boat pitch is the mechanical linkage.
- 3) High-performance rowers on average are more accurate than their coach about the performance of the boat. They are therefore a valuable resource for identifying effective

movement patterns that are difficult to be distinguished via magnitude-based variables alone. This is especially true in the rowing environment, where reliable speed information can be challenging, due to variable weather conditions, and what is fast and what is successful may not equate to the same thing.

- 4) A real-world example of the behavioural dynamics model is established, demonstrating the emergent nature of perception and action. Here rowers match their velocity to that of the boat, in order to couple and “row with the boat” during the recovery phase of the stroke. The rower adjusts his/her oar angle speed early during the recovery, in order to maintain a coupling to the boat’s speed. This early change in oar angle speed corresponds to a late drop in boat pitch, which in turn produces less drag on the boat. In this way, a more energy-efficient state is maintained for longer, as demonstrated via a faster boat speed.
- 5) The creation of a new biomechanical measure about boat pitch velocity during the drive phase is a valuable performance measure. The measure of *maximum boat pitch velocity* demonstrates a greater effect on performance than previously established biomechanical measures. In particular, by achieving maximum boat pitch velocity early on in the drive phase and consequently reducing the drag on the boat, a faster boat speed can be achieved.

## CHAPTER 2

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### INTERPERSONAL, INTRAPERSONAL, EXTRAPERSONAL? QUALITATIVELY INVESTIGATING COORDINATIVE COUPLINGS BETWEEN ROWERS IN OLYMPIC SCULLING

This chapter comprises the following paper:

Millar, S. K., Oldham, A. R. H., and Renshaw, I. (2013). Interpersonal, Intrapersonal, Extrapersonal? Qualitatively Investigating Coordinative Couplings between Rowers in Olympic Sculling. *Nonlinear Dynamics, Psychology and Life Sciences*, 17, 425-443.

#### Overview

Coordinative couplings are commonly classified as interpersonal and intrapersonal. Interpersonal coordination is normally thought of as between organisms but a subset can also be considered where the co-actors movements are coupled to an environmental rhythm. This can be termed *Extrapersonal coordination*. This study explores how coordination is achieved in a situation that demands that at least one actor makes use of extrapersonal sources. In this case multi-seat rowing, where one actor cannot see the other one behind him/her. A qualitative approach using experiential knowledge from expert rowers (N=9) and coaches (N=4) was used to examine how interpersonal coordination was achieved and maintained in 2 person rowing boats. It was reported that where possible, both rowers coordinated their movements by coupling with an invariant provided by the boat. This invariant is underpinned by perception of water flow past the boat; which is in turn used to determine changes in acceleration – “rowing with the boat”. Bow seat also identified the rower in front and stroke seat identified the looming of the stern as viable alternative sources for coupling.

## Introduction

Achieving coordination can be viewed as a problem underpinned by the need to master multiple degrees of freedom in order to achieve organismic goals (Bernstein, 1967). How this problem is resolved depends on the constraints associated with the individual, the task and the environmental dynamics (Newell, 1986). Coordination is commonly achieved by the grouping of degrees of freedom to form softly coupled functional units of control to meet the demands of the particular task (Bernstein, 1967). Researchers classify two primary categories of coordination relevant to these coupling tasks. These are; Intrapersonal coordination; when a body segment acts in a coupled relationship with another body segment (Gibson, 1986) and Interpersonal coordination; when one individual coordinates his/her movements with the behaviour of another (Schmidt & Richardson, 2008). Interpersonal coordination can also be considered between an individual and the environment where the co-actors movements are coupled to an environmental rhythm (Temprado & Laurent, 1999). A convenient distinction can therefore be made between coordination that directly links the actions of organisms and those organisms coordinating with environmental information sources; the former being interpersonal coordination and the latter being extrapersonal coordination. This permits the consideration of separate constraints driven problems and the examination of independent effects with respect to coordination. Furthermore, it is possible to examine both specifying and non-specifying variables that contribute to coordinative couplings (Jacobs & Michaels, 2007). That is to say, information used for the purpose of interpersonal or extrapersonal coordination may be considered in terms of what information is used, when it is used and how it is used.

A dynamic systems approach to interpersonal coordination (Richardson et al., 2005) looks at the movements of people as an entrainment process of behavioural and biological rhythms, rather than a consequence of pure mechanics (Bernieri & Rosenthal, 1991). This approach assumes that rhythmic movements can occur naturally in humans and that coordination is constrained by the same dynamical process of self-organisation that shapes the functioning of interacting physical oscillators (Kelso, 1995). Research directed toward a better understanding of intentional and unintentional interpersonal coordination (Richardson et al., 2007) reinforced earlier work of Kelso (1995) and Temprado & Laurent, (2004) who found that coupling is

commonly strengthened or supported by visual perception of movement. Richardson et al. (2007) looked at two people sitting on rocking chairs manipulating the amount of visual information available about the other participants' movements. They found that when more visual information was available to participants, stronger interpersonal coordination occurred and that coordination; emerged without instruction. In other research, Richardson et al., (2005) showed that entrainment occurred unintentionally in a pendulum-swinging task where the explicit goal of the task was to solve a puzzle problem connected to the pendulums. Thus, interpersonal coordination may be seen as an unintentional consequence, rather than the goal of a given task as it emerges from the search to find optimal task solutions.

In an attempt to extend the scope of research and theory around interpersonal coordination, Schmidt, Fitzpatrick, Caron, & Mergeche (2011) used a system involving cans and metronomes to demonstrate how entrainment can occur within a far wider range of systems than merely those linked by vision. The general point was made that while interpersonal coordination is most often seen as a combination of two or more central nervous systems via the optic array, there is no reason to assume that other co-coordinative combinations cannot be facilitated via alternative media or perceptual systems. In the same paper, Schmidt et al., (2011) also provided evidence that individuals trained in a multi-point task, demonstrate stronger couplings than those that do not. To summarise, interpersonal coordination may emerge intentionally and unintentionally as part of goal directed movement it does not necessarily demand access to the optic array and coupling will benefit from practice. Less clear is how these coordinative couplings are formed and facilitated in multi-joint tasks. More specifically there has been no direct examination of emergent couplings between individuals that do not function via the optic array. Previously, researchers have identified that sporting tasks are an ideal task vehicle because they illustrate how 'processes of perception and action: (a) are mutually enabling, (b) are embodied within the actor-environment system, (c) function in a task-specific manner, and (d) are dependent on nested, interacting constraints inherent to particular performance contexts' (Davids, Glazier, & Renshaw, 2005, p. 36). One suitable task vehicle for examining emergent interpersonal coupling when no direct visual connection between the co-actors is available is (paired) Olympic Rowing.

Olympic rowing has the goal of racing a set distance (usually 2000m) in the shortest time possible. This type of rowing commonly involves more than one person in a boat and consequently success relies on the relationships between two or more actors. When examining success, traditional rowing literature has predominately analysed the major biomechanical factors of stroke length and power (Baudouin & Hawkins, 2004). Such an approach typically finds that bigger rowers with larger physical capacity can produce more power (Barrett & Manning, 2004). However, coordination between rower's movements is also seen as an important factor in determining boat success (Baudouin & Hawkins, 2002; Hill, 2002; Kleshnev, 2008; Rekers, 1999). Indeed, the technical skill level (intrapersonal and interpersonal coordination) of rowers producing elite performances was found to be as important as their physical power when determining success (Smith & Spinks, 1995). This was a point underlined by Coker (2010) who found that stroke length and power (output) did not show a direct relationship with boat velocity. With this in mind interpersonal coordination would appear to be an essential part of the skill that allows rowers to exploit basic organismic constraints such as size and power. Unlike other activities that exploit interpersonal coordination as part of successful performance, one actor has to achieve this coordination without seeing the other. For example, in a paired boat, rowers are sat one behind the other in such a way that the person sat at the rear of the boat (stroke) looks on to the water and the stern only. It may be argued that highly successful (and practiced) rowers are most able to resolve this problem in order to coordinate for maximum effect. In solving this problem rowers must exploit the broader properties of the perceptual array, inviting questions that are of interest and relevance to understanding interpersonal coordination as it occurs in well practiced real-world task.

Early studies by Gibson (1986) and Lee (1976) established the link between perception and action with respect to coordinative tasks. Accordingly many sports require athletes to interact with environmental information in order to achieve effective coordinated performance for successful task execution (Davids, 2002). Indeed, at the elite level, athletes are able to exploit environmental information, often created by their own actions (e.g. Davids et al., 2008; Seifert, Button, & Brazier, 2010). Interpersonal coordination for rowing is nested within a task solution that demands coupling between actors and the environment. Specifically, rowing requires a well-timed oar placement for each stroke that reflects the behaviour of rowers, the boat and

water conditions. Consequently rowing can represent two problems; 1, the acquisition of the (intrapersonal) coordinative function required in rowing (specifically the catch), which is unique to the rower and 2, the ability to row in time with others (interpersonal coordination). Varying informational sources available to experts can offer the option of multiple solutions to the same problem; that is through degeneracy, athletes can achieve the same outcomes with different coordination patterns (Edelman & Gally, 2001; Rein, 2007; Renshaw, Davids, Shuttleworth, & Chow, 2009). Experts, as with novices will perceive situations for what actions they afford the rower (Davids et al., 2008). Experts have shown the ability to extract increasingly relevant information from the sensory sources available (Araujo, Davids, & Serpa, 2005; Robertson, Tremblay, Anson, & Elliott, 2002) and not just rely on one information source, but rather on specifying information that is consistently available across all performance environments (McRobert, Williams, Ward, Eccles, & Ericsson, 2009; Robertson et al., 2002). The most reliable and consistent information available to actors is also known as high order or invariant information, (Gibson, 1986) and it is this invariant information that informs specific actions. How actors become experts, therefore could be dependent on their ability to attune to and exploit higher order invariants that match their global level of developed skill.

In line with the work of Schmidt et al. (2011) two broad questions are to be addressed. Firstly, in situations where two central nervous systems are being mapped but not directly via the optical array, what perceptual variables underpin this process? Secondly, how do the variables recruited as part of the entrainment process influence inter and intrapersonal coordination? These questions suffer a problem of context. Here, investigators studying perception action couplings in rowing are confronted with multiple perceptual sources and many more likely couplings within such a complex movement. A strict reductionist approach to this problem may see multiple relationships examined in an eliminative fashion. Such a process would be time consuming and vulnerable to turning up meaningless relationships by chance. Furthermore as Kelso (1995) points out, the purely numerical description of the skill would fail to represent a complete understanding of a movement within a dynamic system. He discusses the need to generate models suited to the level of analysis and places the modeller in the position of deciding what should be looked at. On this point we go further than Kelso's original argument by using expert knowledge to drive modelling decisions and reduce the number of "inspired

guesses” as Kelso puts it. This approach has proved successful in previous research (Greenwood et al., 2012; Passos, Araaújo, Davids, Gouveia, & Serpa, 2006); as experts can provide experiential knowledge that extends and enhances the understanding of performance. Expert knowledge can be described mimetically in line with the approach of Dawkins (1989), in that it is shared information about task solutions communicated between experts. Practice and competition provide a suitable evolutionary environment from which only the fittest (most useful) knowledge units will emerge. The usefulness of expert knowledge units is understood and retained by experts as a consequence of prolonged, high level practice and competition. Put another way, expert knowledge is the result of an eliminative evolutionary process that may be interrogated in order to address the problem of examining appropriate dynamic relationships.

From an ecological psychology viewpoint, individuals are inseparable from the environment used to study them (Gibson, 1986, 1998; Vicente, 2003). This presents problems when examining real world tasks in laboratory situations where the context may alter the resulting task and organismic responses (Araujo et al., 2007; Brunswik, 1956). Qualitative examination of task related expert knowledge goes some way to addressing this problem in that data reported is grounded in the real world context. Memes held by expert rowers and coaches about successful rowing can also be considered a task constraint on their performance (Renshaw & Davids, 2004). In essence the images (or mental models) these experts have regarding the performance they are striving to achieve will guide their actions.

The aims of the present study are to qualitatively research experiential knowledge from expert rowers and coaches, regarding:

- 1) What critical factors experts think influences rowing performance?
- 2) What is the role and importance of coordination to successful performance?
- 3) What perceptual information expert rowers use to establish and maintain interpersonal coordination?

As a result, it is hoped that a greater understanding will be gained with respect to interpersonal and intrapersonal personal coordination; specifically those instances that are not supported by direct visual perception.

## Methods

### *Participants*

Nine past or present elite rowers who had competed at the Olympics or World Championships and four coaches who had coached crews at least one Olympic Games were interviewed. Participant's demographics are shown in Table 2.1; showing the number of times a Coach or Rower either attended the World Championships or Olympic Games. Germane to the requirement for expertise was the demonstration of success in order to validate the extraction of expert memes, experience alone was not considered sufficient to meet this requirement. Consequently, the expert rowers had to be elite level international competitors and have competed at one or more of the following: Commonwealth Games, World Championships or Olympic Games. The coaches satisfied Côté and Sedgwick's (2003) criteria of being considered experts if they had completed a minimum of ten years of experience and developed several international-level athletes; this indication of expertise has been expressed by the number of years coaching the National team.

Table 2.1: Participant experience competing at World Championship or Olympic Game

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	Rower									Coach			
Participant	1	2	3	4	5	6	7	8	9	1	2	3	4
Appearances	4	8	4	4	2	5	2	8	11	7	24	9	13

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### *Procedure*

Following institutional ethics approval participants were contacted through a letter of invitation in cooperation with a national rowing organisation. They were informed of the purpose, potential benefits of the study and given details of their expected involvement. As the method of data generation was via semi-structured interview, a pilot interview was performed and reviewed by the interviewer and a colleague with experience in qualitative methods applied to sport. This

review resulted in refining the interview content, semantics and order of questions for the interview guide. The primary researcher then conducted all the semi-structured qualitative interviews; six occurred face to face, and three by telephone with the rowers and all four face to face with the coaches. The interview length permitted full exploration of the issues concerned and was between 30-50 minutes with the rowers and 50-90 minutes with the coaches.

At the start of the interview, participants signed a consent form and were reminded of the purpose of the research, but there was no mention of current theories to ensure their responses were not biased. The interview guide was based on previous expertise and talent development research in sport (Côté, Ericsson, & Law, 2005; Weissensteiner, Abernethy, & Farrow, 2009). After rapport building conversations and broad questions to familiarise them with the inquiry theme (e.g. I would first like to discuss your experience as a rower/coach. Can you outline your experience for me?), participants were asked about what they considered as important in order to perform successfully in rowing? This was a broad question that utilised participants experiential knowledge gave them an opportunity to highlight any important factors they perceived influenced rowing performance. A semi-structure interview approach allowed an ordering of questions depending on the responses from participants; these questions were designed around the following themes;

- Theme 1           What critical factors experts think influences rowing performance?
  
- Theme 2           What is the role and importance of coordination on successful performance?
  
- Theme 3           What perceptual information expert rowers use to establish and maintain interpersonal coordination?

### ***Analysis***

Interviews were transcribed verbatim and analysed. Specifically an inductive approach was employed, which followed previously established guidelines (Biddle et al., 2001; Krane et al., 1997; Patton, 2002; Tesch, 1990). Two experienced researchers undertook analysis, one with significant rowing knowledge, and the other with experience in the academic study of skill acquisition. Strictly speaking this was not a grounded approach as researchers performing the analysis had a priori knowledge of rowing and coordination, however no confirmatory model

was proposed. Transcripts were read over several times to familiarise the researchers with the material. This allowed early forms of analysis (Braun & Clarke, 2006) by looking for meaningful units of information (i.e. segments of text that were comprehensible by themselves and contained one specific idea, episode, or piece of information (Tesch, 1990). Units generated by each researcher were then compared and debated for the production of agreed, higher order (meta) themes (Charmaz, 2006). These higher order themes were then reverse validated in order to find agreement with primary data units. In order to cross validate themes and thereby examine “best fit”, the final phase of analysis involved theme verification with an additional researcher who had experience as a coach and as a rower (Biddle et al., 2001). The additional researcher read un-coded transcripts and was asked to highlight sections that she felt agreed with a list of themes that emerged from the initial analysis and also identify data that fell into new categories. This process resulted in the inclusion on an additional lower-order theme in the model about rower “feel”, but there was no change to the higher order themes.

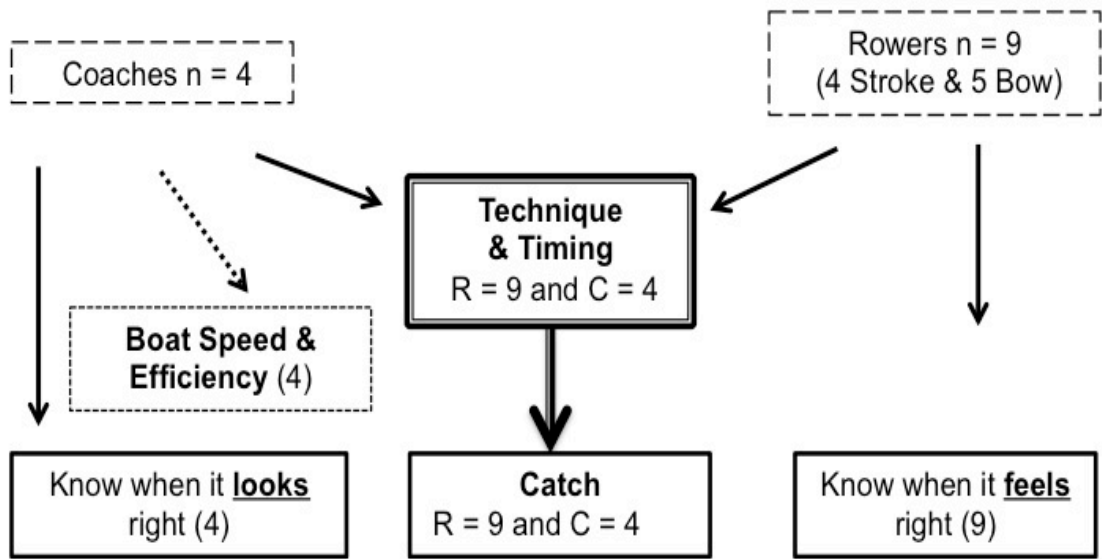
## **Results**

Results of the three themes from the semi-structured interviews will be discussed in relation to, under 2 broad headings;

Heading 1: Critical factors for performance in rowing (Figure 2.1)

Heading 2: Coordination model - in two person rowing boats (Figure 2.1)

Headings one will examine the critical factors experts felt influences rowing performance, plus the role and importance of coordination on successful performance. Heading two, examines at a deeper level how coordination is achieved and controlled. Here, coordination will be looked at broadly, but also according to how boat seat position impacts on the coordinative solutions that emerge.

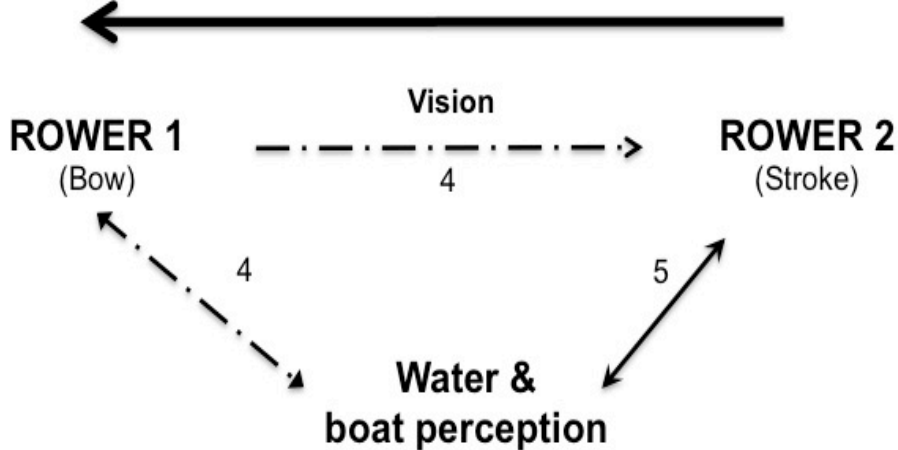


Subconscious

**Coordination model – in 2 person rowing boats**



**Boat Direction**



Bow seat can see the rower in front (stroke), the boat and the water. Stroke seat, can only see the boat and water.

Figure 2.1: Critical factors for success in high-performance rowing and the importance of coordination for successful performance in rowing

## ***Critical factors needed to perform well, and the importance of coordination for successful performance in rowing***

### **Coaches**

Boat speed and efficiency (4 of 4 coaches)

*The most important thing is the boat speed. That's the first thing I look at; and then why isn't it going fast? (Coach 4 (C4))*

Coaches appear to use global information in order to make initial critical decisions drawing on a single information source (perception of speed) rather than making deliberate discriminations of technical quality with respect to particular actors. This allows for an appreciation of higher order invariants and may suggest an ability to attune to the affordances available to the rowers (Fajen et al., 2009).

Know when it looks right (4 of 4 coaches)

*There is a definitive look; there is a very clear look, it just looks right (C2)*

*Good rowing is in tune with the boat; it is a visual thing about the speed of the crew coming forward relative to the boat speed (C3)*

These comments support previous research which showing that expert coaches are more attuned to specific movement information cues (Araujo et al., 2005; Robertson et al., 2002) and are able to detect high order invariants about performance.

### **Rowers**

Know when it feels right (9 of 9 rowers)

*It is a feeling that makes me decide when to put the blade into the water, rather than any timing point and we could tell if we were getting it right off the catch, because the boat felt light (R5)*

The ability to 'feel' when to put the blade into the water may be related to sharing a haptic channel of information between the actors, as the stiffness of the boat enables a physical connection between actors (van der Wel, Knoblich, & Sebanz, 2011). Expert rowers also

appear to have an appreciation of higher order invariants in order to successfully monitor and perform the rowing skill. The consciously perceived variables, “feel” and “lightness” describe abstract perceptual and kinematic relationships. In so far as the adjectives used do not address visual relationships, it seems reasonable to argue that these variables are unique to rowers and not shared with coaches.

### **Rowers and Coaches (Technique and Timing)**

#### Technique (4 of 4 coaches & 9 of 9 rowers)

Rowers and coaches stressed the need to achieve a high level of intrapersonal (multi-limb) coordination ‘technique’ (Figure 2.1).

*Success is about ability, leverage, & technique; technique is the biggest thing. (C1)*

*You learn that technique will make the boat go faster; it is not all about hard work (R5)*

Not surprisingly, these results support research indicating that successful performance at elite level goes beyond power (organismic constraints) toward how it is applied (intrapersonal coordination). Specifically, poor technique is understood to cause the boat to decelerate rapidly and lose momentum at the end of a stroke (McBride, 2005; Smith & Spinks, 1995).

#### Timing (4 of 4 coaches & 9 of 9 rowers)

Rowers and coaches placed great emphasis on interpersonal coordinative timing between rowers’ actions (Figure 2.1).

*I would say that we need to gel as a combination more, probably above anything else (R4)*

The timing of individual rower’s movements with other crew members has been highlighted as having considerable impact on performance (Baudouin & Hawkins, 2002; Hill, 2002; Rekers, 1999). Notably rowers speak about the goal of interpersonal coordination between themselves and other rowers, rather than intrapersonal coordination (personal technique) goals.

*I guess if you are rowing really well together, you don’t have to be quite as fit and strong (R8)*

This result confirms research in rowing biomechanics (For example, Anderson, Harrison, & Lyons, 2005; Coker, 2010; Rekers, 1999; Smith & Spinks, 1995), which found that successful

rowing is determined by more than purely stroke power and stroke length. Although, rowers stressed the importance of performing together it remains unclear (at this point) which part of the stroke needs to be most tightly coupled (if any). The rowing stroke can be separated into the following sections; *Catch* (oar placement into the water) *Drive* (oar moving through the water) *Finish* (extracting the oar from the water) and *Recovery* (moving back to the catch with the oar out of the water).

#### Catch (4 of 4 coaches & 9 of 9 rowers)

Interpersonal coordination at the catch is the ability to correctly apply respective blade forces as a unit to a desired target (the water). The experts in this study stressed the importance of the catch as having the greatest influence on boat performance and therefore needed to be most tightly coupled between themselves and the boat (Figure 2.1).

*I think ultimately the timing of the catch is a deciding factor in performance (C2)*

*If we haven't got the catch timing right, it is pretty detrimental to the rest of our stroke (R2)*

This finding from the rowers and coaches' supports previous literature, which states that proficiency of technique at the catch, was thought to be a determinant of performance (Kleshnev, 2008; Kleshnev & Baker, 2007; McBride, 2005).

#### **Conscious limitations (Subconscious)**

When these expert coaches and rowers were asked to try and explain the details of blade placement; they struggled to summon suitable adjectives and answers became vague; suggesting that control resides beyond conscious inspection.

*Sorry I am being a bit imprecise, but it is a bit imprecise, it is very hard to define it. But if you can do it, you know when you are doing it and if you can see it, you see when it happens (C2)*

*You know straight away if you are out of time, because you are so close and there are only two of you in the boat, you can just feel it. It is not something that you think about, it is just something that you know, you know the feeling when you are in time, and you know the feeling when you are out of time – sorry I don't know, I can't explain it more than that (R9)*

The struggle to detail what constitutes some of the higher-order invariants discussed earlier is to be expected. Bernstein's (1967) levels of control model proposes four levels of control, only two of which are open to conscious inspection. Furthermore the model posits that control may be placed in the system according to the demands of the task. The lack of conscious knowledge can then be seen as the direct result of becoming skilled where responsibility for coordination and control is delegated to subordinate levels of the central nervous system (CNS) (Turvey, 2007). The actor then makes use of the self-organising movement system dynamics that are most functional for the task (Peh, Chow, & Davids, 2011). This also supports the gradual attunement to higher order invariants. As skill increases there should be a shift from basic couplings to higher order couplings and the control over these couplings can take place at the subconscious levels of tone and synergy (Bernstein, 1967; Turvey, 2007). Consequently, consciousness is directed toward monitoring as opposed to deliberate control.

### ***How interpersonal coordination is achieved and controlled*** (coordination model)

The clear message from the expert rowers and coaches is that coordination is about connecting movements of rowers with that of movements of the boat.

*The boat is giving the rowers the timing, and telling you when the blade should go in. You should feel when it is time to put the blade in and you need anticipate it, because if you think about it, you're lost it and it's too late (C1)*

*I think timing is everything basically; but it is more important to be in time with the boat, than anything else (R3)*

The rowers and coaches reported that it is not the rowers' intrapersonal movements, but rather how they coordinate their actions with the movement of the boat that is important. Apparent interpersonal coordination is facilitated here via an extrapersonal information source. That is to say that it is not the perceived actions of the respective rowers that determines the coupling but rather the perceived action of the boat. The boat movement (i.e. up and down) action following stroke  $n$  can be seen as determining the timing of stroke  $n+1$ . What is unclear is the extent to which this extrapersonal variable specifies movement in so far as it may determine *when* or describe *how* a stroke is performed. This finding supports the contention of Schmidt et al,

(2011) in that two central nervous systems are being entrained by means other than the perception of directly specifying perceptual variables.

### **Rowing in different Seats**

Stroke and bow seat rowers both explained how they used environmental information to help them achieve interpersonal and extrapersonal coordination. They differed in their responses largely as a consequence of the task constraints unique to their position in the boat. Bow seat can see stroke seat in front of him/her, but stroke seat cannot see bow seat behind him/her.

### **Bow seat Vision + Water and Boat Perception (4 Rowers)**

Although the actor in bow seat can see the person in front of him/her and can achieve interpersonal coordinative in the manner commonly studied (Kelso, 1995; Schmidt & O'Brien, 1997; Schmidt, Richardson, Arsenault, & Galantucci, 2007; Turvey, 1990), he/she describes the use of additional perceptual information at the same time.

*I would use the boat; water going past the boat compared to the side of the boat, but also compared it to her (my partner's) back. It would be her body coming forward and I would look at the boat run and sort of look at the way her seat moved. I don't know, it is sort of a mental calculation, I can't explain but you've got the seat moving at one speed, you've got the side of the boat dead still and the water moving as well and you would get the timing off that (R8)*

*I have always got my timing by looking at water going past the boat by my rigger – just out of my right eye and that is something that I have always got my timing from. I could tell how much the boat was slowing down, by comparing the boat run to the side of the boat. (R4)*

The information used here is a mixture of optic flow from the water and looming information from the actors back seen in front.

*You should be able to feel with your hands and keep the same pressure kept there and through to your feet, pressure on your feet. Pressure on your back, you should be almost be able to feel through your backside the flow and the timing. (C4)*

Coaches continue to demonstrate that their position (typically on the river bank or in a speedboat, at a 90° angle to the boat direction) dominates the affordances to which they attend. What is also confirmed here is the scope of variables to which an actor can attune.

*People are taught to watch the person in front for timing, which is wrong, because if you are looking for the timing you are late. You are too late. You have to feel the timing (C2)*

*Our coach tells us not to follow the person in front of you; rather feel the timing yourself, so that everyone is picking up the same time (R4)*

Whilst looming information provided by the back of the rower in front can be useful (and appeared to be utilised by rowers; see above) it is deemed not as effective as other sources by coaches and rowers.

#### **Stroke seat Water and Boat Perception (5 Rowers)**

Stroke seat occupies a unique position where he/she has to perform with someone while not being able to see that person. In an attempt to solve the movement problem of coordinating with the bow seat rower and with the movement of the boat, stroke seat can use vision; but in quite a different way to bow seat. Stroke seat would look at the movement of the stern (end point of the boat) in front of him/her, to help time his/her movement.

*I look at the stern of the boat; I could see how fast the stern lifts out of the water when you are catching it, you know, if the stern dips too far down. If it does dip too far down you know you are killing the boat run (R1)*

*When you are coming to the catch the boat will dip, but you want the least time possible at the catch, dipping and sinking. You want the boat to be up and keep moving, so there isn't an extra bump as you go through the drive. (R4)*

These quotes emphasise how the stroke seat rower can use looming information from the boat; as it provides useful information about boat action. This is followed with:

*I can see the speed of my hands going towards the catch, and I can see the water, the puddles in the water and I can get some timing from that. (R6)*

*The stroke seat can look at the movement of the boat coming towards them and that water disappearing down the stern. That visual information of the boat is really important in the stroke seat (C3)*

*You get a feeling from the boat and the water sort of running underneath you (R3)*

There is the potential for both stroke and bow seat rowers to make use of different looming sources in order to gain information about catch timing. However, they both also appear to make use of optic flow information concerning the passage of water passed the boat. These commentaries suggest that perceptual sources used for interpersonal coordination appear to not to be directly specifying and for the most part are extrapersonal. Broadly speaking, the data supports the view that any variable can be mapped onto two central nervous systems for the benefit of interpersonal coordination as well as the closed mechanical systems of the type discussed by Schmidt et al. (2011).

*I try to tell them to row with the boat and feel the boat (C2)*

From a dynamic systems perspective the present data confirms that interpersonal coordination is an emergent phenomenon (Coey, Varlet, Schmidt, & Richardson, 2011; Richardson et al., 2005). During the course of performance it would appear that skilled rowers learn to attune to specifying information to exploit their perception of the boat's movements.

## **Conclusions**

This study looked at how interpersonal coordination is achieved and maintained in two person rowing boats, where only one actor can see the other. It paid particular attention to the perceptual variables that underpin this process and how they are used. Qualitative data suggests that expert rowers attune to extrapersonal invariants as a primary resource in order to achieve skilled interpersonal coordination. The data indirectly supports the contention of Schmidt et al. (2011) insofar as coordination may be facilitated through means other than *direct visual perception*. However vision still provided information that *indirectly* specified coordination through the perception of optic flow. Data also supports the view that a key determinant of rowing success is the coordination of individual properties in order to exploit organismic constraints such as strength and power.

Traditional methods of understanding coordination have tended to adopt a purely quantitative approach based on kinematics and boat performance data. The present study demonstrates a method by which this approach may be rationalised in pursuit of better dynamic systems models. In line with others (e.g. Greenwood et al., 2012; Passos et al., 2006), experiential knowledge from expert coaches and rowers did allow a distinctive new set of findings to emerge that have not yet been explored or previously understood. This fits with Kelso's (1995) approach to understanding dynamic systems at different levels of modelling; in turn extending understanding with respect to coordination in naturalistic settings.

The key findings from this study are;

- 1) Skilled performers make use of high order invariants, i.e. the properties of which extend beyond conscious inspection.
- 2) Successful rowing pairs exploit common invariants where possible. However solutions also demonstrate a degree of perceptual degeneracy, where alternative sources can be used which are unique to the circumstances of the respective actors in the coordinative couplet.
- 3) Broad models of dynamic systems can be drawn up using qualitative methods.

In contrast to more traditional views on rowing performance (Barrett & Manning, 2004; Baudouin & Hawkins, 2004) neither rowers nor coaches made specific mention of stroke length and power. This is not to imply that these aspects are unimportant, but rather to suggest that they are a most probably a pre-requisite to expert performance rather than the focus of it. The findings stress the importance of an ecologically driven perspective on skilled performance in that basic organismic potential is harnessed via organism environment mutuality (Davids et al., 2008; Renshaw et al., 2009). Reliance on the environment in this case is tied to optical flow specifically, perception of water passing beside the boat.

The present results do not address findings that practiced individuals demonstrate stronger couplings (Schmidt et al., 2011). However the results do support the view that experts make use of higher order invariants that only become available as a consequence of extended practice and associated proficiency (Araujo et al., 2005; Robertson et al., 2002). That is to say

being able to “row with the boat” is only possible where basic problems of interpersonal coordination have been addressed. It is this issue of higher order couplings that appears to be missing from previous studies into interpersonal coordination. Thus couplings are not only strengthened, but may be functionally different as a consequence of practice.

In talking about “rowing with the boat” experts made clear that coordination was about connecting their movements with those of the boat. This sits well with Rekers (1999) arguing that increased boat drag occurs when rowers do not row in time. Mistimed strokes apply unwanted forces to the boat’s centre of mass, causing “pitch” and “yaw”. These additional changes in boat orientation amount to excess drag. Rowers’ grasp of this problem appears to be grounded in their description of “feel” and specifically concepts of “lightness”. This makes sense in the context of haptic information exchange (van der Wel et al., 2011) facilitated through the stiffness of the boat; which in turn provides information about the application of force relative to each rower. It may be speculated that while optic flow provides timing information, haptic exchange supports a model of correctness. At this point the limitations of the present study become apparent, as experts offered no information on this potential relationship. Difficulties expressed in verbalising knowledge supports Bernstein’s (1967) approach in that movement can be implemented at a subordinate level which is sub-conscious and that the perception that drives it is largely direct. Given that interpersonal coordination is found to display weaker attractor dynamics when only visual information is shared (e.g. Schmidt, Bienvenu, Fitzpatrick, & Amazeen, 1998) which supports the need for skilled actors to exploit degeneracy (Edelman & Gally, 2001).

Bow seat rowers in this study have identified multiple information sources available to them. They used visual information about the rower in front of them and the boat/water information; in particular optical flow information about the water moving past the boat in relation to the rower in front of them. In contrast, the stroke seat had less information available to him/her; he/she could not see the rower behind him/her but did use optical flow again and boat looming information. This connects to findings that stroke seat rowers demonstrate more movement variability (Lippens, 2004). Notably, interpersonal coordination is found to display weaker attractor dynamics when only visual information is shared (e.g. Schmidt et al., 1998), supporting overall, the need for skilled actors to exploit degeneracy (Edelman & Gally, 2001).

The differences in visual information used by respective rowers makes it clear that unique constraints shape the behaviour of each respective rower seated in the boat. This supports the work of Lippens (2004), showing that the bow seat rower in a pair adjusts his/her intrapersonal movement patterns more than his/her stroke seat counterpart. In contrast, traditional views of rowing advocate technique development as being same for each rower in the crew (Kleshnev, 2002a). These findings add to understanding of interpersonal coordination in that they look at the “how” of interpersonal coordination and find latitude for uniquely constrained solutions for each actor supporting the couplet. The rowers here have learned to co-adapt their movements, a key feature of self-organising systems (Renshaw et al., 2009; Richardson et al., 2005).

As stated earlier the common feature of perception for both seats in the boat is optical flow, particularly the passage of water past the boat hull. This presents a parsimonious solution to the coordinative problem supporting a model of efficiency. In particular by having two actors perceive the same variable and respond to it, the opportunities for adjustment are expanded and the scope of functional variability is broadened. This is in keeping with the results of Fine & Amzeen (2011) who demonstrated that system composed of two individuals made more changes at an interpersonal level than an intrapersonal level when solving a coordinative problem. That is to say the interpersonal solution is more effective.

The approach adopted in this study has presented a broad model of how interpersonal coordination may be achieved in the absence of direct visual perception between both actors in a couplet. From this, a more specific measurement driven model may be drawn for further testing that should consequently be better targeted at the measurement level. It is however limited in so far as it cannot render a large proportion of the intrapersonal dimensions of the task. More importantly however, it should also be noted that a study of this type which involves description of a skill rather than the performing of the skill fails to respect the mutuality of the perception action dyad; that is to say it breaks the perception action link. A subsequent study would need to bring the perception action link closer together, in order to further understand how co-adaption occurs in extrapersonal coordinative tasks.

## ***Limitations***

A potential limitation in this study relates to the use of interviews as a technique for establishing information about complex multi-articular actions and how they come together to produce coordinated actions. The use of interviews requires experts to have conscious knowledge at Bernstein's (1967) level of action and be able to verbalise this to the interviewer (Greenwood et al., 2012). It is expected that experts have this elaborative knowledge at the level of action, but at the tone and synergy levels of motor control this would become subconscious knowledge (Bernstein, 1967; Turvey, 2007). An experts' ability to provide conscious knowledge below the level of action is not supported by an ecological dynamics perspective of skilled performance; where expertise involves the perception of affordances (Seifert et al., 2012), and how action emerges from the ability to perceive action possibilities. Consequently, expertise from an ecological dynamics perspective requires experts to attune to specifying information to support their actions, rather than having conscious knowledge; like interviews can necessitate.

## CHAPTER 3

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### ATHLETE AND COACH AGREEMENT: IDENTIFYING SUCCESSFUL PERFORMANCE

This chapter comprises the following paper:

Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hopkins, W. Athlete and coach agreement: Identifying successful performance. *International Journal of Sports Science & Coaching*. In press.

#### Overview

Traditional coaching views the coach as an informed resource and the athlete as a reflection of expert knowledge. Recent approaches have criticised a strictly coach driven model of expertise, and in doing so have acknowledged the unique and developing knowledge of athletes which emerges from extended practice. The growth of the athlete's contribution in the coach-athlete dyad invites interesting questions about the usefulness of athlete knowledge and the changing role of the coach. Athlete-coach agreement was assessed via a triangulation of quantitative boat speed data from a single sculler and matched to phases of successful rowing that rowers and coaches both agreed on. Coach and rower were able to identify when the boat was travelling its fastest or slowest. However, when the performance was marginally faster or slower, they disagreed, and generally the rowers were more accurate about the performance than their coach. Implications for contemporary coaching practices are considered.

## Introduction

Traditionally designated roles for a sport coach include planner, observer and provider of feedback (Kidman & Hanrahan, 2011). These roles require a coach to have knowledge sufficient to determine success and where necessary, what needs to be changed in pursuit of improved performance. Kundson and Morrison (2002) support this view, stating that a critical step for coaches is communicating to athletes desired changes necessary for better performance. This approach sees the coach as an informed resource and the performer as a reflection of expert (coaching) knowledge. Recent approaches have criticised a strictly coach driven model of expertise and in doing so have recognised the coach-athlete dyad as a more appropriate approach, acknowledging the unique and emergent knowledge coaches and performers bring to the process as a result of extended practice (Davids, 2012; Kidman & Hanrahan, 2011). Recognising the importance of athlete knowledge complementing coaching knowledge in the coach-athlete dyad invites interesting questions about the value of athlete knowledge and the changing role of the coach as a reflection of practice.

Considering expertise development from the perspective of the athlete-coach dyad takes into account how the ability or level of the athlete influences the nature of the coaches' role. In the situational coaching model proposed by Hadfield (2005); non-expert athletes are viewed as needing considerable resources and support, while experts are more self-reliant and proficient. This view is commensurate with the established knowledge of the differences between non-experts and expert performers, with experts being able to demonstrate more sport specific knowledge, and attune to specifying patterns by utilising different sources of information to that of non-experts (Côté, Baker, & Abernethy, 2007). As a result the relationship athletes have with their coach alters from one of dependence to independence as they become more expert, with control moving towards the athlete and away from the coach (Hogg, 1995). A coach-athlete dyad that promotes this philosophy develops performers who have a greater understanding of the performance-environment relationship and ultimately increases their independence and self-reliance (Fajen et al., 2011; Fajen et al., 2009).

Coaches, like athletes also develop from non-expert to expert with practice (Young, Jemczyk, Brophy, & Côté, 2009). The development and behaviour of coaches has been continuously

linked to their ability to recognise athletes needs and structure the training accordingly (Côté & Sedgwick, 2003). This means that as they become more expert, they use practice time more effectively by designing learning environments that simulate competition scenarios and are based on the needs of the athletes they are coaching, and then give specific rather than generic feedback and structure sessions (Horton & Deakin, 2008).

As one might expect, expert athletes and coaches maintain unique perspectives on successful performance, contingent on their differing roles and previous experiences (Millar et al., 2013). Coaches' understanding of performance is based on vision of the athlete and whatever direct prior experience they have of the particular task, whereas the expert athlete relies on unique vision, haptic feedback and sound perception gathered in real-time interactions with the dynamic environment (Millar et al., 2013). Furthermore, the athlete is party to both what they intend to do and also what actions they took. This combination of intention and resulting action should provide a more nuanced and effective model of outcome correctness (Araujo et al., 2006; Davids, 2012). Accordingly, it may be argued that as both over time athlete knowledge will be superior to that of the coach in some aspects of performance. With this in mind, it could be anticipated that the highly skilled athlete would be able to make judgements about performance with greater accuracy than the coach (Hadfield, 2005).

Defining good performance is a key role of the applied sport scientist when working with coaches and athletes. With the benefit of technology, sports scientists nowadays have access to varying devices by which to evaluate performance (e.g. Haake, 2009). In sports like rowing, swimming or cycling, measures of speed are most frequently used to assess ongoing performance (e.g. Smith & Hopkins, 2012). However, in rowing, while a boat impellor (device placed on the bottom of the boat to provide boat speed) may provide an objective measure of the peak speed achieved in each stroke, it is only a univariate source of information that suffers limitations in real world environments. For example, it does not consider how wind direction or force, water current or the quality of the previous stroke impacts on one isolated stroke. Expert performance is reflective of an adaptive, functional relationship between a performer and his/her environment resulting in an ongoing adaptation of individual's actions to dynamic interacting constraints (Araujo & Davids, 2011; Seifert et al., 2012). Consequently, defining good performance cannot be achieved by just referencing a non-contextual metric, as that is not

necessarily the most useful information for a coach when seeking to improve skill; nor does it take into account the unique individual, task and environmental constraints acting to underpin performance (Gibson, 1987; Renshaw, Davids, & Savelsbergh, 2010).

One route to assessing emergent performance in rowing is to assess the scope of agreement or disagreement over the perception of key performance variables such as the effect of an individual stroke on boat speed within the context of the coaching dyad. Determining the relative abilities of athletes and coaches to assess performance is not a trivial issue. As discussed earlier, specific feedback is an important factor in developing expertise, but if this feedback does not accurately reflect performance it can lead to inappropriate focus in future practice. In a recent qualitative study by Millar, Oldham & Renshaw (2013), it was established that expert rowers and coaches were confident in their ability to predict performance. In particular coaches said they could identify successful performances by simply looking at the rower and boat relationship while the rower was performing. Coaches described a strong link between their decisions about correctness and the point where the rowers put the oars in the water (called the catch), relative to the perceived speed of the boat. Similarly, athletes said that when they are performing, they too could identify success via “the catch” of the stroke and the passage of water past the boat. However, given the previous discussion, it could be expected that skilled rowers may be able to provide better judgements about performance than coaches who do not have access to the same information sources as rowers who are dynamically interacting with their environment. Consequently, using boat speed (in the context of the ongoing rower-environment interaction) as a basic index of effectiveness should make it possible to examine whether coaches and expert rowers share similar or categorically different perceptions of successful rowing. Therefore, this study seeks to examine if rower and coach judgements about the same performance match each other and if boat speed data supports their judgement.

## **Methods**

### ***Participants***

Participants were eight rower-coach dyads consisting of a national level single scull rower (four lightweight men (below 72 kg), three-heavyweight woman (above 59 kg), and one lightweight

woman (below 59 kg) aged 19 to 24 with 4 to 9 years' experience) and their individual coaches (36 to 61 y). Rowers were all current members of Rowing New Zealand's talent development program and had represented New Zealand at age-level world-championships. All coaches had satisfied Côté and Sedgwick's (2003) criteria of being considered experts in that they had greater than ten years coaching experience and had developed several international-level athletes. A local University Ethics Committee provided ethical clearance and all participants were informed of the procedures and gave their written consent.

### ***Procedure***

A predominantly qualitative/idiographic method was adopted with respect to the rower/coaches' experience alongside quantitative methods with respect to rowing performance. A common criticism of sports performance research is that it is not conducted in a naturalistic setting and is thus or (is) incomplete (Cross & Lyle, 1999; Pinder et al., 2011). In an attempt to obtain data in the performance environment, this study used a triangulation of quantitative boat speed data from a single sculler and matched it to phases of rowing that rowers and coaches described as successful at the actual moment(s) when performance was taking place.

Each rower performed two ten-minute phases of sub maximal rowing at 20 strokes per min (spm), while their coach was travelling in a speedboat beside them. Sub-maximal rowing is 80-85% of  $VO_2$  max and was selected because it is the level at which over 80% of training is performed (Nolte, 2005). Before the rower and coach went on the water to perform, they were told that every ~ 30 s during the two ten-minute phases they would be asked to say if that nominated stroke was a "Yes" or "No" stroke. While performing on the water, the researcher said "Now" during the drive phase of the rowing stroke (after the catch), enabling a response from both the rower and coach; either Yes the boat was travelling fast because they had timed the catch well or No the boat was not travelling fast because they had not timed the catch well. Rowers wore a wireless microphone that enabled the researcher to record responses, while at the same time the coach recorded their response on a clipboard in the speedboat. Neither the rower nor the coach was able to hear each other's answer at each data collection point, or know the actual boat speed during the testing period. While the aim was to record judgements from each dyad every 30 s, there were occasions where one or the others response was not

recorded due to stopping a testing period early because of a change in water conditions, and thus 305 events were accurately recorded out of a possible 320.

### ***Analysis***

Data produced four levels of coach-rower agreement: 1) the rower and coach both said *Yes*; 2) rower and coach both said *No*; 3) rower said *Yes* and the coach said *No*; or 4) rower said *No* and the coach said *Yes*. Investigation of the effect of coach and rower agreement and boat speed required quantifying the change in boat speed (in respect of previous strokes) arising from the specific stroke that the coach and rower assessed. In this study an appropriate number of previous strokes for estimation of change in speed needed to be determined. Therefore, a unique method for comparing speed for the given stroke with speed for the previous stroke and with speed for the average of up to seven previous strokes was developed. This was achieved by calculating the standard error of the estimate (SEE), to measure the accuracy of the prediction, and was performed in the Linest function in excel. The number of previous strokes that gave a low SEE, and therefore was most accurate for all the rowers was then used in subsequent analyses. The values of SEE (%) for one through seven previous strokes were 1.32, 1.25, 1.26, 1.27, 1.31, 1.33, and 1.35. Although the minimum occurred with two previous strokes (1.25), a decision was made to choose three strokes to reduce the possible effect of between-stroke fluctuations as documented by Hill & Fahrig (2009), and to obtain a boat speed over a period of ~9 s, which is similar to the 8 s recommended by Martindale & Robertson (1984) and Smith and Spinks (1995).

### ***Statistical analysis***

This was completed in two parts: 1) four levels of coach and rower agreement were compared using a Kappa test; 2) rower-coach agreements were compared with boat speed. Statistical analysis of the rower-coach agreement compared was achieved by coding the four levels of agreement into values of three dummy variables, each having a value of 0 and 1, representing the coach's and rower's assessment of the success of the stroke. The coach variable was 1 when only the coach considered the stroke successful. The rower variable was 1 when only the rower considered the stroke successful. The rower-coach variable was 1 when both rower and coach considered the stroke successful. These variables were the predictors in a multiple linear

regression, in which the change in boat speed was the dependent variable. The intercept in the regression model represented the change in boat speed when both the coach and rower assessed the stroke as being unsuccessful. The regression was performed with the Linest function in Excel and provided statistics for the mean change in boat speed for the four levels of agreement, the standard error of the estimate in the regression model, and standard errors for intercept and the coefficients of each of the predictors.

## Results

### ***The four levels of coach and rower agreement***

A total of 305 strokes where the coach and rower had to make decision that either the boat movement was successful or not, were analysed via a kappa test (see Table 3.1). The result indicates only a 'slight to fair' agreement between coach and athlete (Viera & Garrett, 2005).

Table 3.1: Athlete and coach assessments of success of strokes (%)

		Athlete		
		Yes	No	Total
Coach	Yes	38	21	59
	No	18	23	41
	Total	56	44	100

Kappa result agreement coefficient = 0.20 (95% confidence intervals 0.09 to 0.31)

### ***Coach rower agreement and boat speed***

The four levels of coach-rower agreement are presented in Figure 3.1, which shows the change in boat speed at the nominated stroke relative to the mean of the previous three strokes. The situation where both the coach and the athlete both said Yes showed the greatest change in boat speed compared to the previous three strokes.

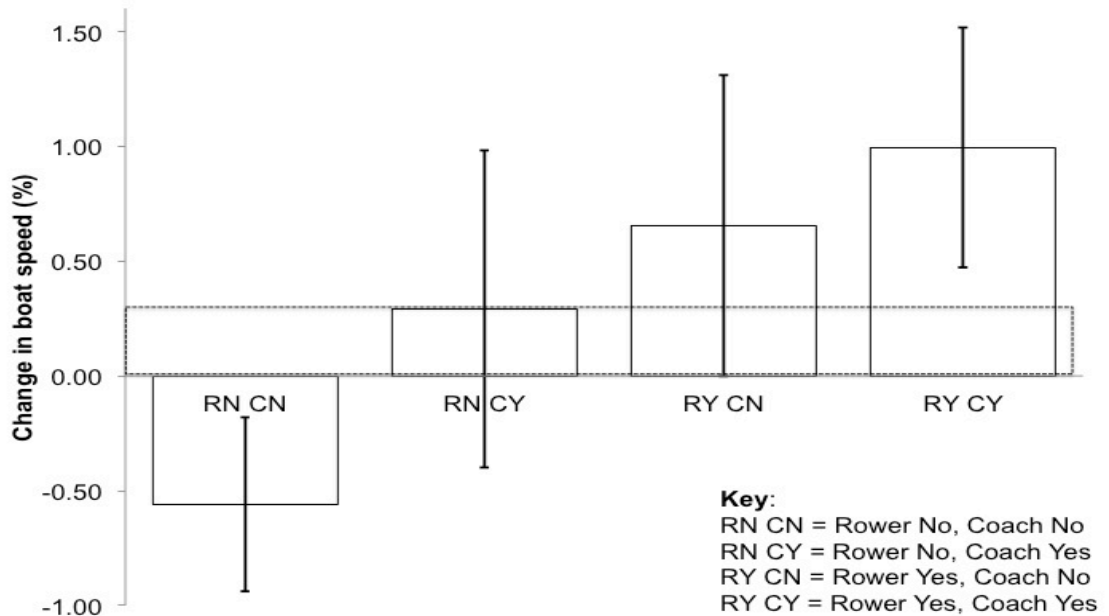


Figure 3.1: The four levels of coach-rower agreement

Figure 3.1 represents a change in boat speed at the nonimated stroke relative to the average of the previous three strokes. Mean values and standard diverations for each of the 4 categories are; Rower No Coach No  $-56; \pm 0.38$ , Rower No Coach Yes  $0.29; \pm 0.46$ , Rower No Coach Yes  $0.65; \pm 0.64$ , Rower Yes Coach Yes  $1.00; \pm 0.52$ . The line inserted at  $\pm 0.3\%$  represents the smallest worthwhile change in boat speed which can effect a change in medal prospects for interational rowers. For the two levels of agreement where the rower and coach did not agree (i.e. rower No coach Yes or rower Yes coach No), the rower was more accurate at identifying faster strokes than their coach. Whenever the rower made a Yes judgement (i.e. RY CN) about performance they were always accurate, whereas when the coach said Yes (i.e. RN CY) sometimes the boat was quicker, but at other times it was actually slower. This can be identified by an average change in boat speed of  $0.29\%$ , but with a large standard deviation of  $\pm 0.69$ .

In order to see if the change in speed was significant in that it would result in a 'better' or 'worse' overall performance. Figure 1 has a line inserted at  $\pm 0.3\%$ , which represents the smallest worthwhile change in performance time over 2000m for international rowers to effect a change in medal prospects (Smith & Hopkins, 2011). When selected strokes were above the  $0.3\%$

threshold for the smallest worthwhile effect, the rower and coach both said Yes at the same time (1.00%) or just the rower said Yes (0.65%).

## **Discussion**

The aim of this study was to examine the confident claims of the interviewed rowers and coaches in Millar et al., (2013). In particular, that they could make accurate judgements about the same performance, which was supported by matching their judgements to boat speed data. This is an important issue for coaching practice as it can help answer the question about the most appropriate pedagogies for developing expertise. This question was explored by triangulating rower and coach judgements about boat speed with the actual speed of the boat. This required the development of a new innovative methodology that enabled a specific stroke to be considered in the context of ongoing performance. The findings provide evidence that rowers are in the best position to make judgements about their own performances, but also provide some support for the claims of the coaches. While both coaches and rowers were able to identify when the boat was travelling significantly faster, disagreement was also found between rowers and coaches and this was at its greatest when performance was only marginally faster or slower. In these situations, rowers made the greater number of accurate judgements. These findings are in line with our expectations and commensurate with previous empirical studies, conforming that more expert athletes are able to access and report knowledgeable with respect to their performance (Borg, 1998; Fajen et al., 2011; Garcin & Billat, 2001). This is an important finding as it shows that athletes can provide knowledge about performance that is not accessible to a coach. In line with the ecological approach of Gibson (1987), expert performers 'in action' are attuned to the affordances of the environment, that is, the informational constraints available for them to use. Thus, athletes have a unique perspective about successful performance and are potentially important contributors to the coaching process (Hadfield, 2005).

These findings are significant when considering the dynamic of the coach-athlete dyad providing support for the view that traditional coaching models that have the coach as the sole determinant of successful performance and provider of feedback (Knudson & Morrison, 2002) are outdated. In contrast, the interactionist model of coaching proposed by Hadfield (2005) is

supported with both coach and athlete providing important complimentary contributions to the coaching process, particularly with respect to providing feedback. The findings in this study do not de-value the importance of the coach but do question the nature of their role when working with developing experts. Expert coaching has been found to be linked to their ability to recognise athlete's needs and structure the training accordingly (Côté & Sedgwick, 2003). It would seem that to this end, expert coaches would do well to embrace the knowledge that athletes have to offer. Consequently, the accuracy of athlete judgements in this study suggests that coaching high-level performers becomes a different undertaking to that promoted by the traditional model and supports a more complimentary athlete-coach relationship (i.e. Young et al., 2009). To some extent this is supported by data showing that the fastest performances corresponded to those occasions when both coach and rower agreed on successful instances.

These results support the adoption of more athlete-centered approaches to coaching (Kidman & Hanrahan, 2011) and shared decision-making is strongly advocated. A feature of this approach is for coaches to see athlete's knowledge of their performance as a resource that can provide complementary information sources when designing learning (Greenwood et al., 2012). A shared knowledge approach brings together coaches' indirect perception of the environment to access their prior 'knowledge about' the environment and adds to the rowers' direct perception of information from the environment, that is, their ongoing 'knowledge of' the environment (Silva, Garganta, Araújo, Davids, & Aguiar, 2013). Whilst we believe that this approach captures more of the available informational constraints underpinning the extra-personal co-ordination of rowers in boats (Millar et al, 2011) than a coach-alone approach can, some caution must be given in that previous work has shown that performers can actually do more than they can say. While, verbalizing and reflecting on their own performances may help individuals to become more attuned to informational constraints (Silva et al., 2013), there also needs to be caution about the risk of asking athletes to describe movements while they are performing. Skillful athletes can attune to key environmental information or affordances in order to act, and the detection of these affordances may not at the conscious level of awareness of the performer (Seifert et al., 2012) Therefore, asking athletes to simply make a judgment about performance, rather than a describing a skill while moving would be recommended.

The role of the coach in an athlete-centred approach is somewhat different to the traditional view of the coach as director or transmitter of knowledge. In this approach, the coaches' value is based in the ability to help facilitate learning by guiding the learner in their search for specifying information (Chow, Davids, Hristovski, Araujo, & Passos, 2011) and promoting engagement with the environment (Fajen et al., 2011). Athlete knowledge can be elicited via questioning by the coach to encourage developing experts to attune to key information sources that underpin perception-action and enabling the emergence of adaptable, functional coordination patterns with his/her environment (Araujo & Davids, 2011; Seifert et al., 2012). This may see the coach confirm the intentions and judgements made by athletes, a process through which new knowledge about performance may be generated. In order to utilise a rower's ability to make judgements about their own performance coaches would also need to encourage awareness of performance with their rowers. Helping develop perceptual awareness of the rower could also result in more independent and self-reliant performers, who are more able to coach themselves, especially given that training is frequently undertaken in the absence of the coach.

This study brings into question the usefulness of high-tech objective measurement tools when making performance judgements, given rowers' made accurate performance judgements while rowing without relying on boat speed instrumentation. A key question for sport scientists and coaches then, is extra feedback from boat instrumentation equipment required? While boat speed is still an essential indicator of performance in a sport like rowing and the methodology adopted here allowed us to use technology to test our ideas, in high performance sport, evaluating good performance cannot always be achieved by reference to a non-contextual metric that does not take into account the unique individual, task and environmental constraints acting to underpin performance (Gibson, 1987; Renshaw et al., 2010). Consequently, as highlighted previously, rather than providing feedback using metrics such as objective speed, the coach should shift focus towards developing athlete's own feedback mechanisms that refer to knowledge of performance, which are better suited to complex coordinative skills such as in rowing (Wulf, Gaertner, McConnel, & Schwarz, 2002).

## **Conclusions**

A model of experts performance claims that experts have acquired specific knowledge of their own performance (Côté et al., 2007; Hadfield, 2005). Here, this model was tested by comparing coach-athlete agreement about successful rowing performance relative to boat speed, and confirmed that experts are invaluable informants about their own performance. It was established that the coaches and rowers were able to identify when the boat was travelling fast, however, rowers were able to detect the more subtle changes in performance than their coach. Therefore, coaches need to integrate the specific knowledge rowers have about their performance into their pedagogy. The application of unique athlete-environment knowledge, (Davids, 2012; Fajen et al., 2009) supports contemporary approaches to coaching high-level performers; where, the coach should consider athlete knowledge about performance first and then use his or her own coaching knowledge as a supplement. When a coach acts as a facilitator they have a significant role as a reference for the generation of athlete knowledge and an improved outcome of performance.

Potential limitations in this study relate to the question put to the rowers. The question posed to the rowers for identifying successful strokes may have been interpreted as a judgment of speed or stroke quality. Ideally, one or the other should be considered but not both at the same time. Nevertheless, the current approach was sufficient to determine differences between efficiency estimators and was supported by boat speed data. A concluding limitation is the small sample of a rather homogeneous set of advance rowers and that the results should be confirmed in other samples of advanced rowers.

## ***Practical Implications***

1. Rowers were more accurate than coaches at knowing when a performance was successful; relative to the speed of the boat; therefore coaches need to find ways of using athlete knowledge.
2. Coaches cannot identify all the subtle changes in performance; they need the athletes' input & involvement and should be mindful of athlete feedback.
3. If a coach is unsure about the performance, or can't confirm with the athlete, then maybe consider not saying anything, as the coach is not always likely to be right.

4. The use of contemporary coaching approaches, which encourage coaches to help facilitate learning by guiding the learner to search for their own solutions is strengthened. As these approaches support expert models of performance, where learners have increased independence and self-reliance.

## CHAPTER 4

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### VELOCITY MATCHING AND INTERCEPTION: THE CATCHING PROBLEM IN ROWING

This chapter comprises the following paper:

Millar, S. K., Oldham, A. R. H., and Renshaw, I. Velocity matching and interception; the catching problem in rowing. *Human Movement Science*. Under review.

#### Overview

Behavioural dynamic approaches to movement modelling (Warren, 2006) emphasise the emergent nature of couplings between perception and action. This study explored this notion by examining relationships between speed variability and catch timing behaviour in high-performance rowing. It addressed the following key questions: 1) Do top-level rowers use the same speed matching approach for a successful catch in rowing?; 2) Is success characterised by coupling speed to optic flow? Eight single scullers performed two 10-minute phases of sub-maximal on-water rowing at 20 strokes per minute (spm). Every ~30 s rowers reported either “Yes” or “No” about the success and timing of their catch. Results revealed that skilful rowers did couple their actions with the speed of the boat until just prior to the point of interception. They managed this by adjusting the timing of their oar angle movements towards the catch earlier for *Yes* than *No* strokes and maintaining a faster boat speed. In conclusion, this study has provided a real-world example of Warren’s (2006) behavioural dynamics model, where temporal interception emerges from the interaction between the rower and the environment, through a coupling of performer speed to the interceptive objective speed.

## Introduction

In arguing for a model of behavioural dynamics Warren (2006) discusses the changing movement characteristics that emerge from the interaction between actor and environment. In this model seemingly stable, unvarying, adaptive movement patterns are not tied to specific properties of the organism or the environment but to the regularities that emerge from the relationship in action. Consequently, skilful behaviour may be seen as the result of establishing couplings between actor and environment, based on the evolving regularities that occur each time an action is performed. It is significant that these couplings and the actor's accompanying order only transpire when action is occurring. Thus movement behaviour reflects both actor and environment in a unique movement solution specific to that situation and time. In the process of acquiring skills, learners initially explore the perception–action dyad in search of covariates between perception and movement dynamics, and ultimately seek out higher-order invariants that are present each time a given skill is performed (Jacobs & Michaels, 2006; Warren, 2006). Coupling between movement dynamics and perceptual invariants will emerge as skill develops (Fajen, 2013).

Perception–action, as Warren (2006) points out, is cyclical, underpinned by consistent reciprocal relationships. Using locomotion as an example, he describes how suitable application of force results in propulsion, causing optic flow, which may in turn be used to shape further action. Elsewhere it has been argued that coupling is achieved via continuous visual guidance during the unfolding of the movement (e.g. Chardenon, Montagne, Laurent, & Bootsma, 2005; Diaz, Phillips, & Fajen, 2009). Evidence supports the use of optic flow information to detect visual background structure and provide an external reference frame around which a movement system may self-organise (Fajen & Warren, 2007).

Fajen (2007) amongst others describes how performers are able to resolve seemingly complex interceptive problems by virtue of meeting particular conditions of optic flow. For example, the concept of constant bearing angle (CBA) has been used to model interception and collision avoidance between performers and other objects in motion (Bastin, Jacobs, Morice, Craig, & Montagne, 2008; Diaz et al., 2009). CBA is based on cancelling out the rate of change in the bearing angle by varying local approach velocity (e.g. Bastin, Craig, & Montagne, 2006). Here,

performers adjust their speed in order to maintain a particular angle between themselves and the object to be intercepted/avoided. In perceptual terms, success seems to be underpinned by the goal of ensuring little or no change in the rate of optic flow. Evidence from research into catching supports this premise, and success is characterised by speed matching between the performer and object for as long as possible before interception (Chardenon et al., 2005; Lenoir, Musch, Janssens, Thiery, & Uyttenhove, 1999). Under these conditions, the rate of change of flow is kept constant through what is described as an error nulling process (Fajen, 2007). It is noteworthy that at its simplest, optic flow can be described in two parts: the relatively static point of heading and the accompanying change in texture gradient while in motion. The point of heading corresponds with direction and gradient changes that reflect changes in velocity; in this context it is possible to see how simple invariant changes in optic flow may contribute to the successful execution of skill.

The rowing stroke may be described as cyclical, consisting of two phases: impulse and recovery. The duration of each phase is determined by the environment, respective masses, boat dynamics, forces applied and velocity requirements. Successful high-performance rowing requires effective timing of the impulse phase for maximum efficiency and thereby greater average velocity over a set distance (Kleshnev, 2010; Smith & Loschner, 2002). As a locomotor activity, rowing is akin to repeatedly jumping backwards. As an interceptive task it is defined by the need to apply force according to action-specified temporal constraints. This timing action is described as “the catch” (Millar, Oldham, Renshaw, & Hume, in review-b). A successful catch in rowing, as in other forms of interception, requires the performer and specifically the oars to be in the right place at the right time. Recent work by Millar et al. (in review-b) suggests that catch timing requires more than effective speed matching. Timing has to reflect the changing dynamics of the boat, in particular changes in boat pitch position. This problem is not trivial; in the recovery phase that precedes the catch, the boat travels in one direction and the rower travels down the boat in the opposite direction. Furthermore, the oar blade disappears out of sight before interception while travelling in the same direction as the boat, but at a different relative speed. Therefore, successful catch timing requires the harnessing of a series of nested dynamic relationships.

Applying the CBA model to movements such as rowing presents some difficulties. Without a specific target there is no bearing to be taken. However optic flow models can still apply with respect to error nullifying and variation in flow. Evidence presented by Millar et al., (2013) suggested that rowers initially speed match to the water passing the boat during the recovery phase of the stroke and use variability in this information to time the catch point of a rowing stroke. The present study examines this contention in more detail with the aim of verifying whether speed matching and shifts in optic flow constitute a viable strategy for the control of a complex, well-learned task. On this basis some predictions may be made: speed matching will occur; success will be defined by the ability to match for as long as is possible; and the resulting timing will be a unique product of the preceding conditions. In addition, success will be associated with the rower and boat system adopting an economical and energy-efficient movement, reflected in higher relative speed for given strokes (Brook & Sparrow, 2006; Sparrow & Newell, 1998). At the end of speed matching a clear shift in behaviour will be seen that reflects the changing dynamics of the boat and accompanying shifts in optic flow as indicated by velocity change.

The present study uses rowing as a task vehicle and seeks to explore the validity of a behavioural dynamics approach while verifying parsimonious use of optic flow in control. It will have the added benefit of being a truly representative design. Representative design needs to include more than a shared task goal; it needs to consider interacting constraints on movements (Pinder et al., 2011), which in rowing is the dynamics of the boat and rower in a normal setting.

## **Methods**

### ***Participants***

Eight single-scull rowers aged 19 to 24 years with four to nine years' experience participated in this study. The gender and weight division of the participants were four lightweight men (below 72 kg), three heavyweight women (above 59 kg) and one lightweight woman (below 59 kg). Participants were all current members of Rowing New Zealand's talent development programme and had represented New Zealand at age-level world championships. The principal researcher's University Ethics Committee provided ethical clearance. All participants were informed of the procedures and gave their written consent.

### ***Procedure***

The eight single scullers performed two ten-minute blocks of sub maximal on-water rowing at 20 strokes per min (spm). Sub-maximal is considered to be at 80-85% of  $VO_2$  max and is the level at which over 80% of training is performed (Nolte, 2005). Before the rowers went on the water to perform, they were told that every 30 s during the two ten-minute phases they would be asked to state if that stroke was a *Yes* or *No* stroke. While performing on the water, the lead researcher said "Now" late in the drive phase, enabling the rower to say either *Yes* the boat was travelling fast because they had timed the catch well or *No* the boat was not travelling fast because they had not timed the catch well (N=40). The lead researcher was travelling beside the rower in a speedboat and the rower wore a wireless microphone and earpiece that enabled the researcher say "now" and record responses.

Skilled individuals have the ability to distinguish between different stimuli and respond to what they perceive, and they are also accurate in judging the quality of resulting performance (Fajen et al., 2011). The effectiveness of the Borg (1970) scale illustrates the ability of performers to make discrete scaled judgements regarding physiological demand. In an earlier study by Millar, Oldham, Renshaw and Hopkins (in review-a) it was revealed just how accurate athletes are about their own on-water rowing performance when compared with the judgement of their coaches. While rowers and coaches were in agreement about strokes that were clearly faster or slower, for strokes that were marginally faster than the average of the previous three strokes, rowers made the greater number of correct judgements. Therefore using rowers' on-water

performance judgements of successful strokes is an instrumental source of accurate performance information, as they are able to exploit unique vision, haptic feedback and sound perceptions (Millar et al., 2013) that coaches may not have. Consequently, it seems reasonable to base analyses of movement accuracy on qualitative judgements made by skilled performers which can then be verified by quantitative means.

To allow data to be collected on key variables for each *Yes* and *No* stroke, rowers performed in an instrumented boat, equipped with PowerLine™ force gates. While the PowerLine™ software is able to automatically collect data at 50 Hz on 12 independent variables, in line with the study's aims – which focus on the recovery phase of the rowing stroke – only four were used: distance travelled, boat velocity, gate oar angle and gate oar angle velocity. The gate oar angle is measured from the perpendicular position of the oar relative to the boat axis; i.e. it measures how far the rower's oar travels during the stroke (Kleshnev, 2005), while gate oar angle velocity measures the velocity the oar is travelling in degrees per second. The recovery phase (as shown in Figure 4.1), which typically lasts approximately 1.6 s (Nolte, 2005) at 20 spm, starts when the rower lifts his/her oar out of the water at the end of the drive phase and ends when he/she puts the oar back in again (the point known as the catch). The recovery phase can be broken down into three phases that relate to change in velocity (Kleshnev, 2007). During the start of the recovery (~the first 0.6 s), boat velocity slowly decreases (Figure 4.1) and then at half-slide which occurs approximately half way through the recovery (Figure 4.1, point A), the boat velocity is steady (~0.6 s to ~1.25 s), while in the latter phase (~0.35 s before the catch) it rapidly decreases (Figure 4.1, point B). We have termed this concluding section of the recovery the *approach* to the catch.

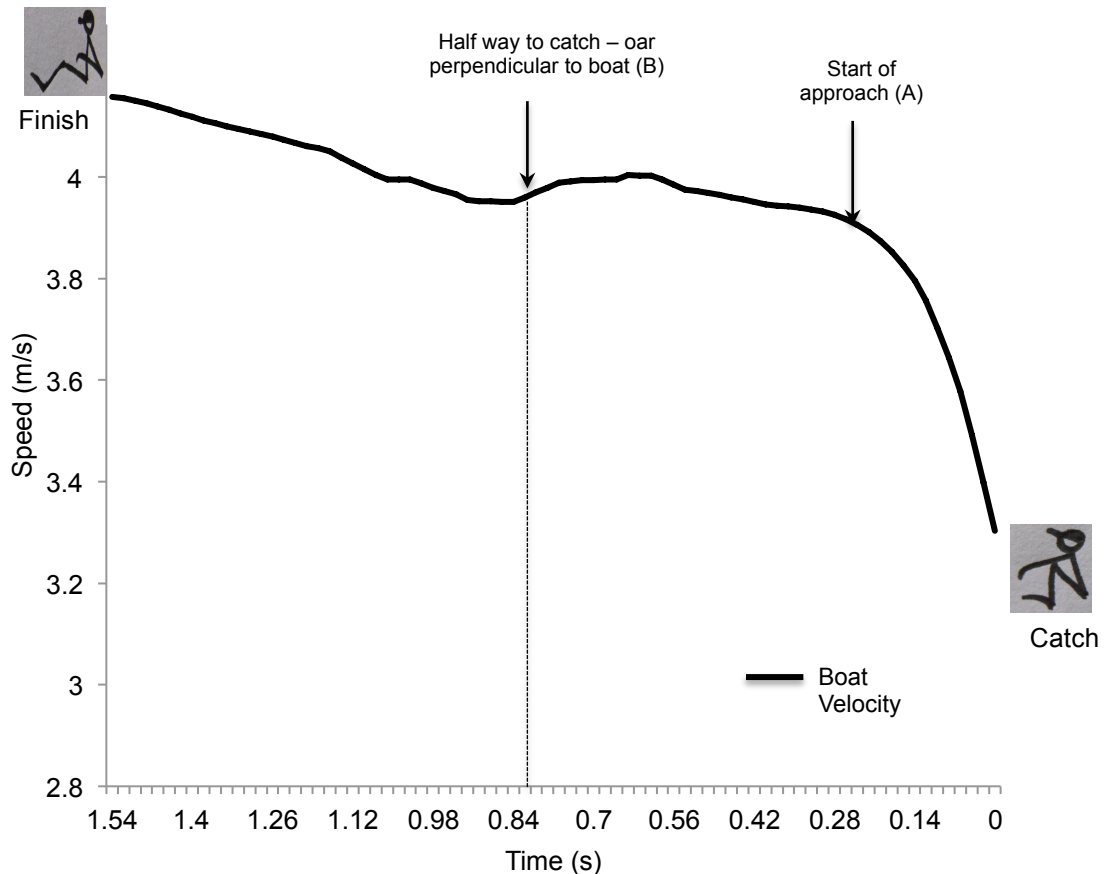


Figure 4.1: Typical boat velocity on the recovery section of a rowing stroke

Data in Figure 4.1 is from rower three for a Yes stroke. Point B is half-slide; while Point A shows the start of the approach phase where boat velocity starts to rapidly decrease towards the catch. Based on the established literature for analysing interceptive actions (i.e. Beek, Dessing, Peper, & Bullock, 2003), the following three measures for each rower's Yes and No strokes were extracted and computed:

- 1) Coupling of performer velocity to interceptive object velocity – in this case, velocity matching of the rower's gate oar angle velocity and the boat velocity, which will be referred to as *coupling*.
- 2) Continuous adjustment of performer's velocity approaching point of interception – in this case the change in gate oar angle velocity prior to the catch, which will be referred to as *oar angle velocity*.
- 3) Boat velocity on the approach phase of the stroke.

## Analysis

Data were sampled at 50 Hz and filtered with a Savitzky-Golay (1964) five-point moving average filter. The point of interception (known in rowing as the catch) is when the oar reached its maximum range and was about to change direction. Initiation time for *coupling* and *oar angle velocity* was defined as when the rower's oar crossed perpendicular to the boat, which is when the oar is at zero degrees. This point was chosen as a constant point that each rower on each stroke passes through while travelling to the catch and is independent of previous strokes or conditions. Movement time consisted of the total time from initiation of the oar crossing perpendicular to the boat to the interception point at the catch.

*Coupling* was established by dividing the change in boat velocity by the change in gate oar angle during the movement time. The change in gate oar angle velocity indicated the speed the rower was travelling at. The point of de-coupling between the rower and boat velocity was determined when the change in boat velocity exceeded one standard deviation from the mean.

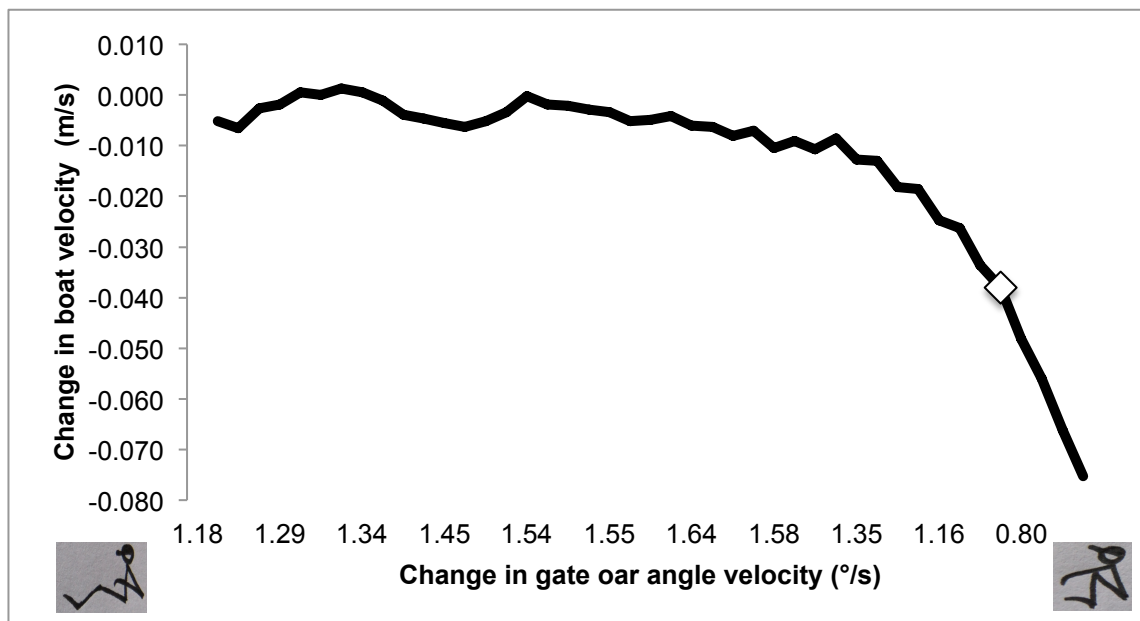


Figure 4.2. *Coupling between boat velocity and gate oar angle velocity*

Figure 4.2 is an example of *coupling* between boat and rower speed from half slide to the catch at 20spm. The diamond shape on the lines indicates the point of de-coupling (a value of one standard deviation from the mean).

*Oar angle velocity* is when the rower slows the rate of gate oar angle velocity by slowing the speed he/she is travelling forward. The time (ms) of *oar angle velocity* was established by

measuring the change in gate oar angle velocity (degrees °) the oar travelled per second. Operationally, this was defined as the point where the change in gate oar angle velocity started to decrease for 5+ data points and was followed by a systemic decline in gate oar angle velocity towards the catch. The gate oar angle velocity decreases when the rowers slow themselves down on the recovery phase on the stroke by applying pressure to the foot stretcher. An example of the changes in gate oar angle velocity during the movement time and the initiation of *oar angle velocity* (bold line) is represented in Figure 4.3. The dashed line indicates boat velocity during the recovery of the stroke.

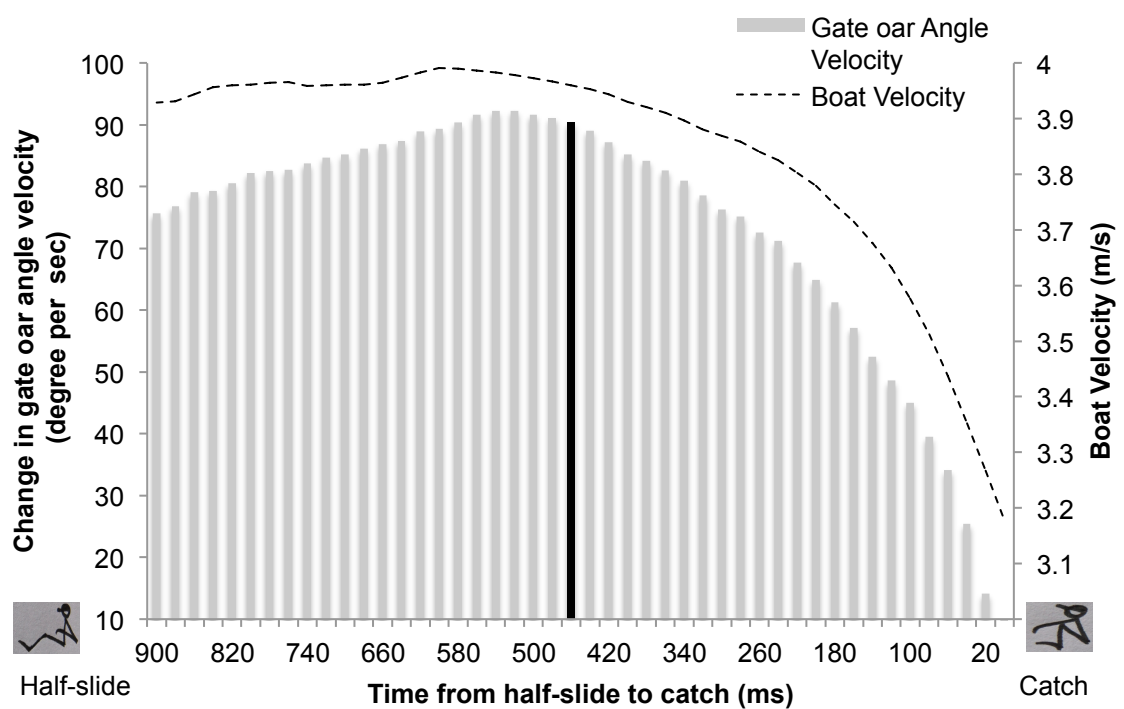


Figure 4.3: Changes in gate oar angle velocity

*Boat velocity of approach phase.* The time (s) and velocity (m/s) on the approach phase was calculated. Operationally, the start of the approach phase was defined as the point when the change in boat velocity decreased for five (plus) consecutive data points, and ended at the point when the oar had travelled to its maximum range and was about to change direction (the catch). See Figure 4.1, point A for an example of the starting point of the approach phase. Velocity on the approach (m/s) was calculated by dividing the distanced travelled on the approach by the time taken, e.g., if the distance travelled on approach was 0.93 m and the time taken was 0.28s, this would equate to a velocity of 3.31 m/s.

## Results

### *Coupling*

For all eight rowers, coupling between the rower's and boat's velocity was maintained for longer in *Yes* than *No* strokes (Table 4.1: *Coupling*). Coupling between the rower and boat's velocity was maintained until 125 ms (SD 12 ms) before the catch for *Yes* strokes, and 155 ms (SD 17 ms) prior to the catch for *No* strokes. Table 4.1 shows that de-coupling between the boats and rower's velocity occurred between 6 and 51 ms earlier for *No* than *Yes* strokes.

Table 4.1: Coupling

*Coupling*. Mean and standard deviation of the time (ms) each rower coupled his/her velocity to the boat's velocity before the catch. The table illustrates *Yes* strokes maintained a coupling of rower and boat velocity for longer and de-coupling occurred just prior to the catch in *Yes* strokes.

	Rowers							
	1	2	3	4	5	6	7	8
<i>Coupling (ms)</i>								
Yes	113 (26)	134 (21)	117 (13)	120 (16)	132 (20)	116 (25)	124 (20)	147 (27)
No	136 (26)	160 (36)	157 (15)	127 (13)	167 (28)	141 (28)	175 (51)	156 (25)

Below in figure 4.4 is an example of *coupling*, where a *Yes* stroke (bold line) and a *No* stroke (dashed line) illustrate the coupling between changes in boat velocity and changes in gate oar angle from half slide to the catch. The diamond shapes on the lines in Figure 4.4 indicate the point of de-coupling. It can be seen that a *Yes* stroke maintained a longer coupling time and de-coupled ~100 ms before interception, compared with a *No* stroke, where de-coupling occurred ~150 ms before the catch.

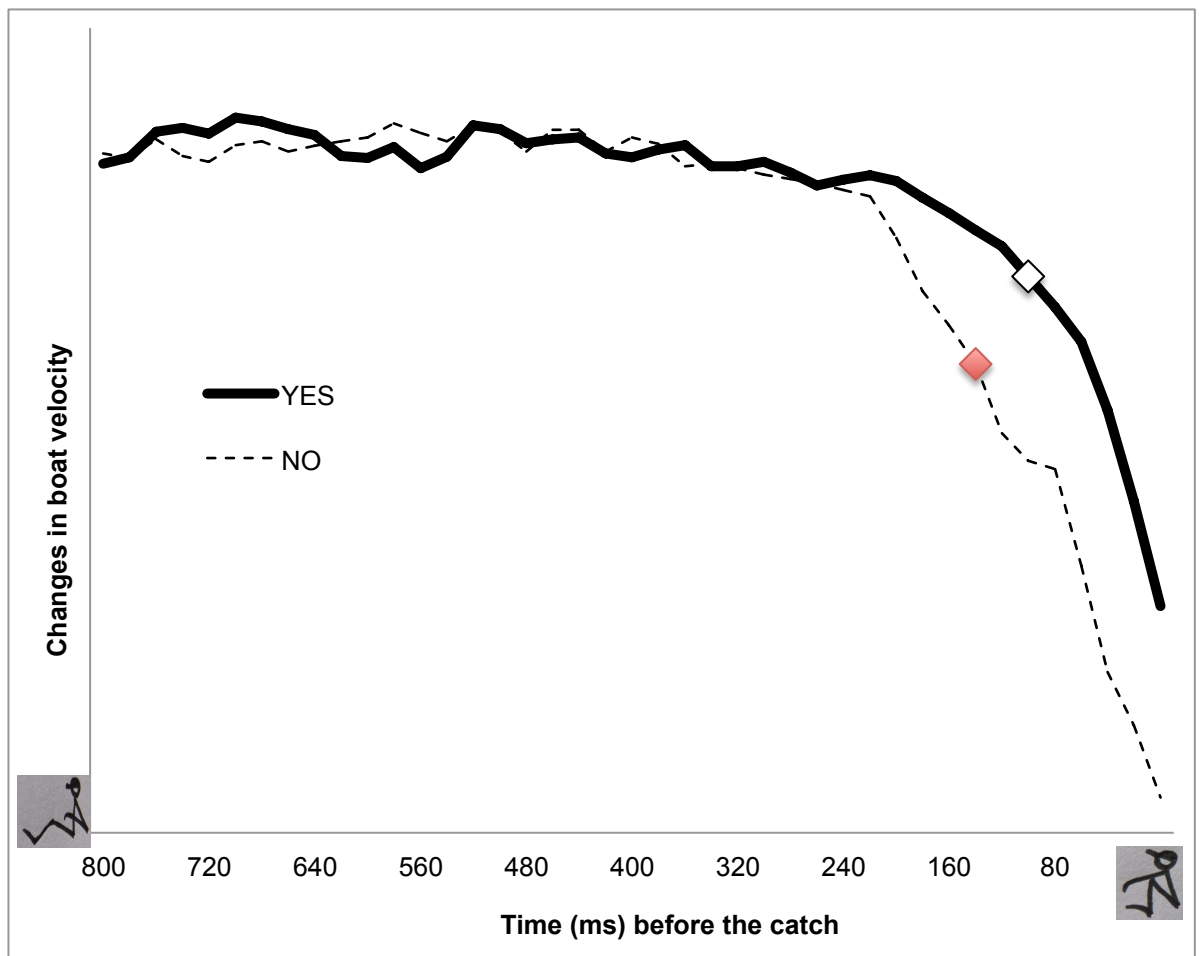


Figure 4.4: Difference between Yes and No coupling

An example of a Yes (bold line) and No (dashed line) stroke changes in boat velocity during movement time. The diamond shape on the lines indicates the point of de-coupling (a value of one standard deviation from the mean). It can be seen that a Yes stroke maintained a longer coupling time than the No stroke.

### ***Rowers' change of oar angle velocity***

A clear finding in this study is that all eight rowers slowed the velocity at which the gate oar was travelling earlier in Yes than No strokes. Specifically, rowers' Yes strokes are noticeable by the earlier adjustment of *oar angle velocity* approaching the catch (Table 4.2:). Changes in rowers' *oar angle velocity* were on average 400 ms (SD 63 ms) before the catch for Yes strokes and 375 ms (SD 67 ms) prior to the catch for No strokes.

Table 4.2: The onset of *Oar angle velocity* for Yes compared to No strokes for each rower

	Rowers							
	1	2	3	4	5	6	7	8
<i>Oar angle velocity (ms)</i>								
Yes	316 (70)	426 (39)	401 (55)	511 (52)	401 (31)	326 (42)	436 (48)	376 (55)
No	299 (39)	412 (44)	389 (42)	495 (45)	362 (65)	297 (57)	414 (52)	332 (79)

An example of the onset of *oar angle velocity* for a No (Figure 4.5a) compared with a Yes (Figure 4.5b) stroke is demonstrated in Figure 4.5. In 4.5a there is a late change in *oar angle velocity* (i.e. 320 ms before the catch) whilst in 4.5b it can be seen that the change in *oar angle velocity* occurs earlier (i.e. 460 ms before the catch) in Yes strokes and tends to match the changes in the boat velocity (dashed line) approaching the catch. The bold line is the onset of *oar angle velocity* i.e. the point at which the rower changes his/her speed towards the catch; the dashed line is the boat velocity during the recovery for that stroke.

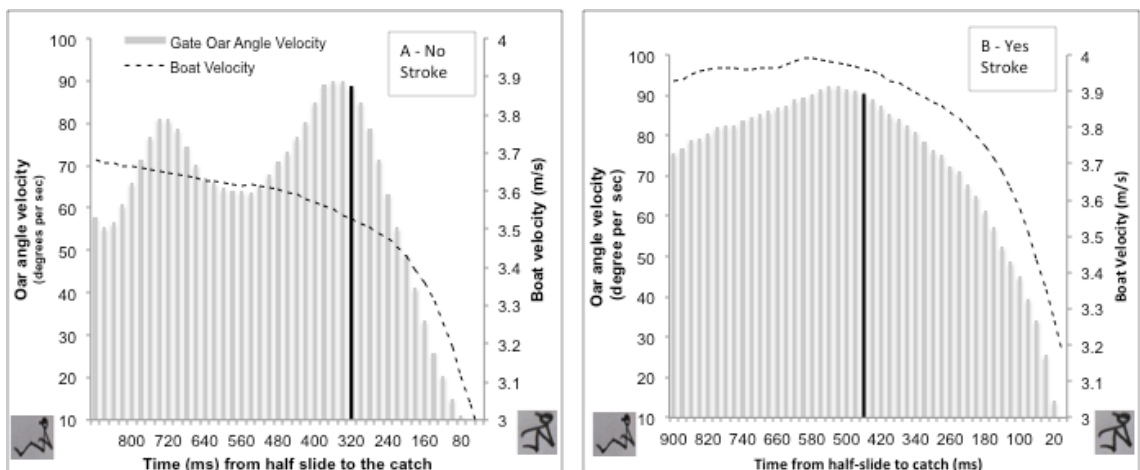


Figure 4.5: Difference in *oar angle velocity* for Yes and No strokes

A summary of the differences of coupling time (ms) between Yes and No strokes is presented in Figure 4.6a, showing that all eight rowers maintained a longer coupling period for Yes than No strokes, and de-coupling occurred earlier in No strokes. A summary of the difference in change in *oar angle velocity* (ms) is presented in Figure 4.6b, showing that all eight rowers adjusted their *oar angle velocity* sooner for Yes than No strokes.

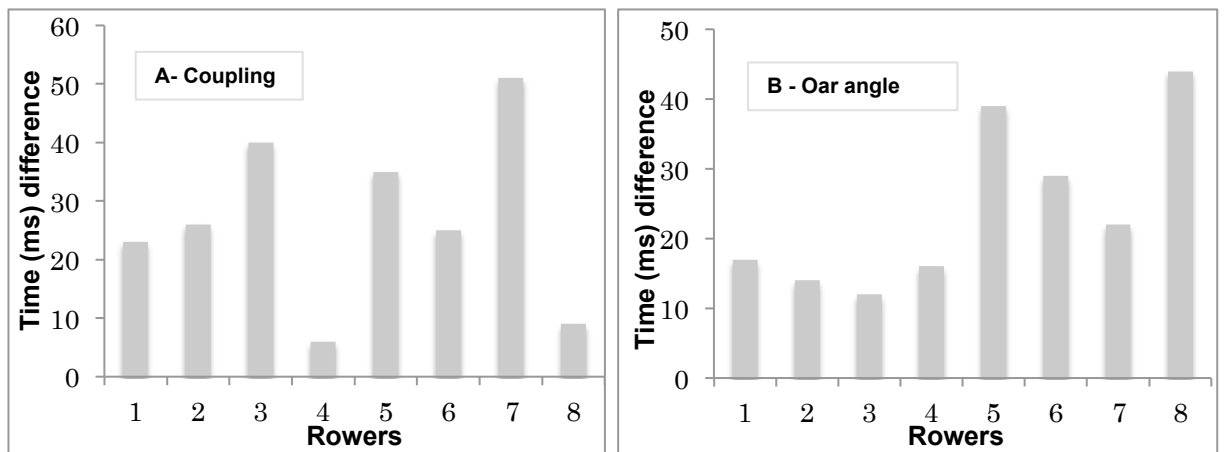


Figure 4.6. Difference between Yes and No strokes for coupling and oar angle velocity

### **Economical and energy efficient**

All rowers had a faster boat velocity for Yes strokes during the approach phase than for No strokes. Table 4.3 highlights the percentage (%) difference in boat velocity between Yes and No strokes. Here, the Yes strokes illustrate a more economical and efficient movement, where the boat did not slow down on the approach phase as much as it did with the No strokes.

Table 4.3: Percentage (%) difference in boat velocity between Yes and No strokes

	Rowers							
	1	2	3	4	5	6	7	8
Boat velocity (%)	1.4%	0.2%	3.7%	1.4%	4.4%	0.3%	2.4%	2.0%

### **Discussion**

The purpose of this present study was to investigate if high-performance rowers use a speed matching strategy where they couple their speed to the speed of the boat in order to achieve successful temporal interception at the catch. Whereas other interceptive tasks or avoidance actions demand that the performer is in the right place at the right time, the catch in rowing is more complex, as it requires careful temporal interception between an unsighted oar under the control of the rower, and the water. This study has demonstrated that this interceptive rowing

task, like fly ball catching, is solved with the same speed matching strategy; that is, coupling of performer speed to the interceptive objective speed. A stroke-by-stroke analysis of each skilful rower clearly indicated that rowers do couple their actions with the speed of the boat, which expert rowers refer to as “rowing with the boat” (Millar et al., 2013). Furthermore, rowers’ self-identified *Yes* strokes were found to maintain a longer coupling period between the rower and the boat, whereas *No* strokes de-coupled earlier. It appears these skilful rowers were able to use key performer–environment informational constraints, in order to maintain a faster boat speed prior to the catch.

On-water success in high-performance rowing in this study is a matching of the rower’s speed to the boat’s speed, up to the point of temporal interception (see Table 4.1). Specifically, it appears rowers were able to cancel out the rate of change in boat velocity by varying their approach speed during the recovery period of the rowing stroke. This strategy seems to allow little or no change in the rate of optic flow, which is known as the error nulling process (Fajen, 2005a, 2007), and has been found to be a successful approach to interception tasks (Bastin et al., 2006). Maintaining perceptual constancy and therefore limiting the change in the rate of optic flow are demonstrated in this study through the rower decreasing his/her velocity to match the decreasing velocity of the boat. This central finding provides quantitative evidence of what expert rowers have described as “rowing with the boat” (Millar et al., 2013).

At the onset of this study it was predicted that successful interception would be identifiable by an economical and energy-efficient movement (Brook & Sparrow, 2006; Sparrow & Newell, 1998). In the case of rowing, economical movement is associated with boat speed and achieving the shortest time to travel a set distance (Smith & Hopkins, 2012). At the top level, race completion time has a very small margin for error; for example, a difference in performance time over a 2000 m race of just 0.3% results in a change in medal prospects at the elite level of international rowing (Smith & Hopkins, 2011). Here all eight rowers had a faster boat speed with *Yes* than *No* strokes (Table 4.3) and for seven of the eight rowers the difference was 0.3% or more, indicating it would make a meaningful impact on performance.

This study has demonstrated that during successful *Yes* strokes rowers continually adjusted to the dynamic performer–environment relationship by recalibrating their actual speed to the

required speed. That is, as the boat speed slowed, they recalibrated their speed to couple to the boat's speed, towards the catch. The rowers' ability in this study to recalibrate during performance is supported in other literature, for example, on intercepting a moving target by hand (Jacobs & Michaels, 2006), how hard to brake (Fajen, 2005b), and recalibration during locomotion (e.g. Rieser, Pick, Ashmead, & Garing, 1995), where participants were on a treadmill pulled by a tractor that was either faster or slower than the treadmill speed and participants recalibrated to the required speed. In addition, research by Savelsbergh, Whiting, and Bootsma (1991) demonstrated how actions prior to interception are based on perceptual changes (i.e. an inflating or deflating ball) – in this case, adjusting to changes in optic flow. However, this study now provides broader evidence, from a real-world task, of participants' ability to recalibrate their speed while performing, in order to meet the task demands.

This illustration of adjustments based on perceptual changes corresponds well to Warren's (2006) behavioural dynamics model, where solutions emerge from the task demands during action. The multivariable task demands of high-performance rowing can be considered as a real-world example of the behavioural dynamics model (Warren, 2006). Here spatial and temporal coordination between the rower and the environment emerge as a result of the rower's movements, which are coupled by perceptual information. For instance, when the rower makes an action, like changing the speed at which he/she travels towards the catch, this produces a change in the system (e.g. the balance of the boat shifts) which the performer must then adjust to. In this respect the rower is not only responding to the environment, but also creating it by the forces he/she applies – i.e. force applied on the foot stretcher (in the boat) to slow him/her down will result in changes in optic flow. This cyclical and reciprocal relationship continues, and new affordances are revealed from the performer–environment interaction that the rower responds to.

The ability of these skilful rowers to couple to the boat's movements on the approach to the catch can likewise be considered as an illustration of an action-based affordance (Fajen et al., 2009). That is, rowers exploit information from the environment that allows them to control their speed and temporal interception. In order to understand how control of speed affords different actions for these rowers, contemporary research in interception (e.g. Dubrowski & Carnahan, 2001; Fajen & Warren, 2004) and locomotor activities was considered (e.g. de Rugy, Taga,

Montagne, Buekers, & Laurent, 2002; Fajen, 2013; Mohler, Thompson, Creem-Regehr, Pick, & Warren, 2007), and an examination of the onset of rower adjustments was made (i.e. changes in *oar angle velocity*). It was found that the skilful rowers in this study made earlier adjustments in their *oar angle velocity* (*Yes* strokes) on the recovery than they did with the unsuccessful *No* strokes. These early changes in *oar angle velocity* (Table 4.2), which slow the rower down, appear to afford a longer coupling between rower and boat speed. Early adjustments appeared to allow additional time for continuous perception–action coupling between performer and environment, rather than making last-minute adjustments close to the catch, as in the case of *No* strokes (e.g. Figure 4.5a). The advantages of early adjustments in interceptive tasks, like placing an oar in the water while moving, have been demonstrated in other interceptive action research. For example, picking up advanced information was associated with successful cricket batting performance (Renshaw & Fairweather, 2000; Renshaw, Oldham, Davids, & Golds, 2007) and with successfully driving through an intersection (Louveton et al., 2012). In this study, an early adjustment in *oar angle velocity* is an example of the dynamic nature of affordances, which allowed rowers to couple to the boat speed for longer.

In conclusion, this study has provided a real-world example of Warren's (2006) behavioural dynamics model, where temporal interception emerges from the interaction between the rower and the environment. Here, the rower–environment system requirements determined what the situation affords for action, i.e. the exact timing between the individual, boat and water conditions of each stroke. It can be seen that the rower exploits this relationship by adjusting his/her *oar angle velocity* early in order to couple with the speed of the boat; while at the same time preserving boat speed. Interestingly, the advantage of attaining a faster boat speed was achieved while the rowers' blades are out of the water and they are not exerting any additional power. Whereas the ontogenic task demands of rowing appear to be complex, it seems that simple and parsimonious mechanisms underlie control of this task.

## CHAPTER 5

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### USING ROWERS' PERCEPTIONS OF ON-WATER STROKE SUCCESS TO EVALUATE SCULLING CATCH EFFICIENCY OF BIOMECHANICAL VARIABLES VIA A BOAT INSTRUMENTATION SYSTEM

This chapter comprises the following paper:

Millar, S. K., Oldham, A. R. H., Renshaw, I., and Hume, P. Using rowers' perceptions of on-water stroke success to evaluate sculling catch efficiency of biomechanical variables via a boat instrumentation system. *Sports Biomechanics*. Under Review.

#### Overview

An effective catch in sculling, which is when the oar enters the water to impart positive force to the boat is a critical determinant of boat speed. Rowers' perceptions of how fast the boat was travelling because they had timed the catch well were used to compare four catch efficiency methods. Three questions were addressed: 1) Would athlete-judged *Yes* strokes be faster than *No* strokes?; 2) Which catch efficiency approach best reflected this judgement?; and 3) What biomechanical variables underpin this outcome? Eight single scullers performed two 10-minute blocks of sub maximal on-water rowing at 20 strokes per minute. Every 30 s, rowers reported either *Yes* or *No* about boat speed and timing of their catch. *Yes* strokes identified by rowers were 0.6 to 1% faster than *No* strokes. *Maximum boat pitch velocity* had the greatest effect on rowing performance. The standardised mean difference score of 0.59 for *maximum boat pitch velocity* was larger than the scores of -0.02, 0.03 and 0.08 for the other three catch efficiency measures. For all eight rowers, *Yes* strokes corresponded to *maximum boat pitch velocity* occurring up to 50 ms earlier than *No* strokes. Achieving *Pitch* earlier in the stroke drive phase may be of most value to performance.

## Introduction

From a biomechanics perspective, successful performance in rowing is believed to occur by increasing the propulsive impulse or decreasing the drag impulse applied to the boat per stroke (Baudouin & Hawkins, 2002, 2004; Kleshnev, 1999). The point at where the oar enters into the water; known as the catch (Richardson, 2005), can affect the forces acting on the boat and blade during the entry and early drive phases of the rowing stroke. Poor technique at the catch can cause the boat to decelerate and decrease the run of the boat, reducing the rowers' effectiveness (Baudouin & Hawkins, 2002; Richardson, 2005). Due to the cyclical nature of rowing, any small variations in force application at this point can result in large effects on performance outcomes. That is, timing of the catch is a crucial part of the rowing as it makes a significance difference to boat speed (Kleshnev & Baker, 2007). This is confirmed at the international level, by a change in medal prospects occurring with the smallest important performance enhancement of just 0.3% (Smith & Hopkins, 2011). Consequently, the relative efficiency of the catch and how it is modelled is of interest to coaches and performers as its influences the impulse than can be created by other phases of the stroke.

Determining a successful and well-timed catch can be problematic, as it has been estimated and operationalized in several ways, including the use of boat instrumentation or coach and rower perceptions. There are three main catch measures in the literature, which attempt to explain successful oar placement at the catch and how this impacts on boat performance. These are time taken to achieve 30% of peak pin force (Kleshnev, 1999), positive acceleration in the direction of the race (Coker, 2010), or a catch slip value automatically generated by a biomechanics feedback instrument for rowing such as PowerLine™. The catch-slip or "slip" refers to the time taken from when the oar first touches the water, to when it is completely immersed (Richardson, 2005).

Reaching 30% of peak pin force was a catch measure designed and tested by Kleshnev in 1999 to evaluate oar entry efficiency. The sooner 30% of peak pin force was achieved, the earlier the rower and boat system started to accelerate. World Champions are known to achieve positive acceleration in the direction of the race, 11 s or 14% quicker compared to national championships finalists (Kleshnev, 2002b). It is thought that rowers who have good technical

ability at the catch are able to achieve a quicker time to positive boat acceleration and may be able to minimise the unavoidable deceleration of the boat that occurs at the start of the drive.

Boat pitch, which is the change in vertical displacement of the bow of the boat in centimetres (Sinclair et al., 2009), is believed to be a valuable contributor to understanding what makes a successful rowing stroke (Sinclair et al., 2009). However, measures of catch efficiency have not been reported in relation to boat pitch. With the advancement of rowing specific biomechanical feedback instruments like PowerLine™; data on multiple dependent variables, one of which is boat pitch is more easily accessible. One method of interpreting the boat pitch displacement could be to consider the change in pitch over time.

An alternative dependent variable that PowerLine™ can provide feedback on is called catch slip. PowerLine™ automatically presents a catch slip angle calculated as the angle that the blade moves whilst less a pre-set threshold force is applied to the pin along the longitudinal axis of the boat. For sculling, a 20 kgF (196 N) is the pre-set catch threshold. A study by Kleshnev (1999) showed that a decrease in catch slip angle is related to increased blade efficiency and performance gains of up to 5%.

A fourth and new alternative method for measuring catch efficiency, is establishing the point of rowers *maximum boat pitch velocity*. The pitch of a rowing boat moves from a bow up orientation as the oar enters the water to a bow down orientation towards the end of the drive phase (Sinclair et al., 2009). *Maximum boat pitch velocity* identifies the point during the stroke when a rower reaches the maximum change in boat pitch velocity; measured in centimetre change per second (cm/s).

In a qualitative study with expert rowers' and coaches (Millar et al., 2013) a successful catch was linked to timing the placement of the oar in the water in conjunction with the pitch movements of the boat. One of the rowers stated: "*I would always be watching the stern for the pick up, rather than letting it sink and jump*". The "pick-up" expert rowers refer to is the stern orientation moving up (while the bow orientation moves down). One method of measuring this pick up as the rowers call it, is calculating how quickly after the catch rowers are able to achieve *maximum boat pitch velocity*. A method for comparing between different measures (like the catch) is to calculate the standardised mean differences for each measure (de Vet, Terwee,

Knol, & Bouter, 2006) and then establish which had the highest score. An unconventional technique for comparing between events is to ask rowers to judge strokes as either successful or not while they are performing.

Performance based judgements are not a new concept; the ability to make them is a fundamental coaching skill and characteristic of expert performance. Skilled individuals have the ability to distinguish between different stimuli and respond to what they perceive. It is however currently uncommon to have these judgements indirectly validate movement analyses. While a boat impellor may measure the peak speed achieved in each stroke, it will not be an effective measure of wind, water current or the quality of the previous stroke. Consequently what an athlete perceives as good and what they perceive as fast can be two different things. Bartlett and colleagues have used the term functional variability to express a skill as one that fits the task at the time and adaptive variability should not be mistaken for “noise” (Bartlett, 2008; Bartlett, Wheat, & Robins, 2007). Being able to identify instances of best fit of movement variability to environmental conditions is an important part of studying applied skills.

The ability of skilled individuals to differentiate between distinctive stimuli and respond accordingly is similar to the Borg (1970) scale. The effectiveness of the Borg (1970) scale illustrates the ability of performers to make discrete scaled judgments regarding physiological demand. A method for understanding rowers' perception of their performance could be through a simple *Yes* or *No* scale, where rowers make a decision as they perform. It would be expected that when asked about the boats' performance; in terms of boat speed and timing of the catch, that strokes which rowers' perceive as successful would be faster than those deemed unsuccessful.

This study aimed to use rowers' performance based judgments to compare four measures of catch efficiency. Therefore, three questions were addressed: 1) Would athlete-judged *Yes* strokes be faster than *No* strokes?; 2) Which catch efficiency approach best reflected this judgement?; and 3) What biomechanical variables underpin this outcome?

## **Methods**

### ***Participants***

Eight single-scull rowers aged 19 to 24 years with four to nine years' experience participated in this study. The gender and weight division of the participants were four lightweight men (below 72 kg), three heavyweight women (above 59 kg) and one lightweight woman (below 59 kg). Participants were all current members of Rowing New Zealand's talent development programme and had represented New Zealand at age-level world championships. The principal researcher's University Ethics Committee provided ethical clearance. All participants were informed of the procedures and gave their written consent.

### ***Procedure***

The eight single scullers performed two ten-minute blocks of sub maximal on-water rowing at 20 strokes per min (spm). Sub-maximal is considered to be at 80-85% of  $VO_2$  max and is the level at which over 80% of training is performed (Nolte, 2005). Before the rowers went on the water to perform, they were told that every 30 s during the two ten-minute pieces they would be asked to state if that stroke was a *Yes* or *No* stroke. While performing on the water, the lead researcher said "Now" late in the drive phase, enabling the rower to say either *Yes* the boat was travelling fast because they had timed the catch well or *No* the boat was not travelling fast because they had not timed the catch well (N=40). The lead researcher was travelling beside the rower in a speedboat and the rower wore a wireless microphone and earpiece that enabled the researcher say "now" and record responses.

In order to collect data on key biomechanical variables for each *Yes* and *No* stroke, rowers performed in an instrumented and calibrated boat, equipped with an impeller, gyroscope and accelerometer, which fed into PowerLine™ force gates. The PowerLine™ software automatically collected data at 50 Hz for boat acceleration, pin force gate oar angle and boat pitch angle. Boat acceleration, pin force and gate oar angle were measured in the X longitudinal direction of boat movement, while boat pitch angle was measured in relation to the horizontal axis of the boat; i.e. the change in vertical displacement of the bow of the boat in centimetres (Sinclair et al., 2009). Laboratory testing has demonstrated that PowerLine™ force gates have acceptable levels of validity; which was represented by a standard error of the

estimate of 8.9 N or less for force, 0.9° (Coker, Hume, & Nolte, 2009). On-water testing of PowerLine™ force gates with elite scullers has showed high with-in and between subject reliability, with typical error less than 1.0% (Coker, Hume, & Nolte, 2008). The PowerLine™ force gates were calibrated to manufacturer's specifications (Coker et al., 2008) prior to testing for each subject.

Based on the established four measures of catch efficiency, each rower's Yes and No strokes were extracted and four catch measures were computed:

1. Time to 30% peak pin force (pkFT)

The time (ms) taken from minimum gate angle to the point at which the force exceeded 30% of the peak pin force in the direction of the longitudinal axis of the boat in that stroke.

2. Time to positive boat acceleration (AccelT)

The time (ms) taken from the minimum gate angle to the point where positive boat acceleration is first achieved in the direction of travel.

3. Time to powerLine force (PLFT)

The time (ms) taken from the minimum gate angle to the point at which the force exceeded 196 N (20 kgF) in the direction of the longitudinal axis of the boat in that stroke.

4. Time to maximum boat pitch velocity (PitchT)

The time (ms) taken from the minimum gate angle to the point at which maximum boat pitch velocity (cm/s) was achieved (shown as time in the highlighted circle in Figure 5.1).

The bilateral average from the two oar gates was taken for each value.

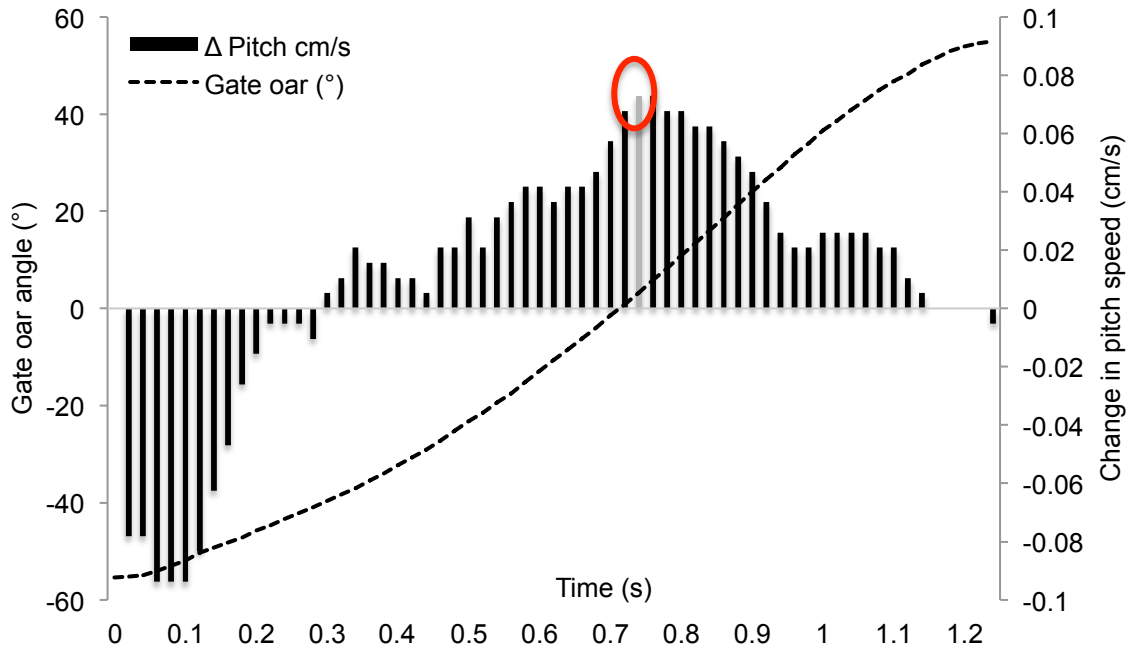


Figure 5.1: An example of oar angle and boat pitch velocity (cm/s) from the catch to the finish at 20 spm. A negative value of boat pitch speed is when the stern is still dropping (bow rising) after the catch and a positive value is when the stern starts lifting. The light line indicates the timing of Pitch after the catch. Data shown are from rower one for a Yes stroke.

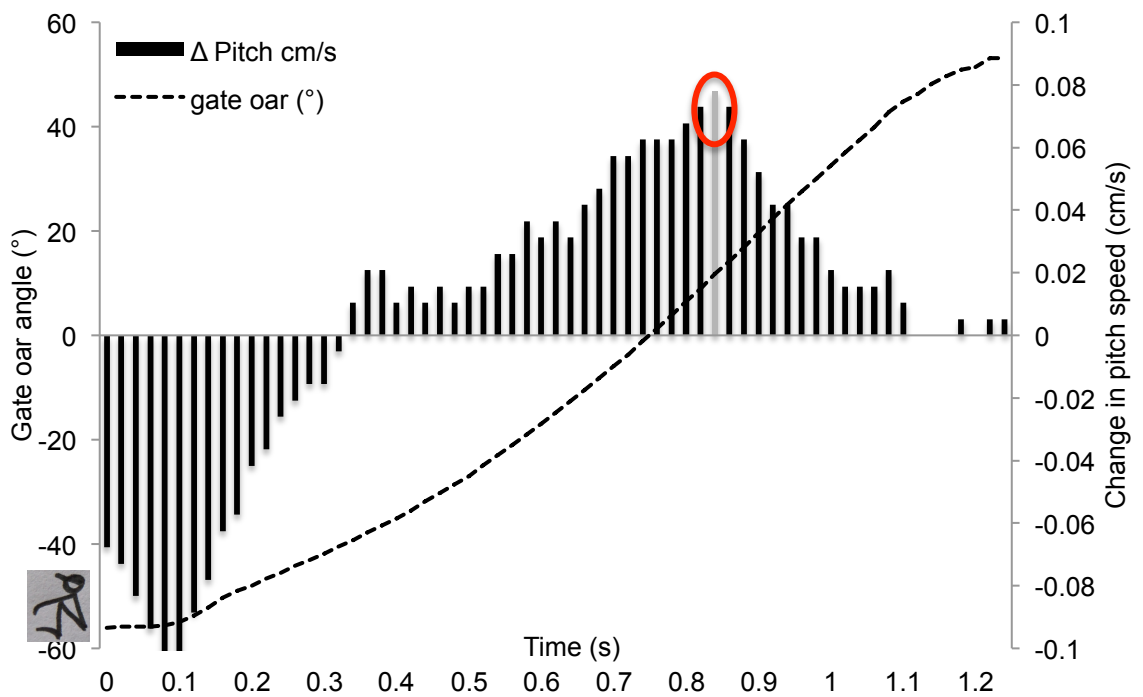


Figure 5.2: An example of oar angle and boat pitch velocity (cm/s) for a No stroke (rower one). The light line indicates when Pitch velocity was achieved after the catch.

Figures 5.1 and 5.2 are examples of oar angle and boat pitch velocity (cm/s) from the catch to the finish at 20 spm. A negative value of boat pitch speed is when the stern is still dropping (bow rising) after the catch and a positive value is when the stern starts lifting. The light line indicates the timing of *Pitch* after the catch. Data shown are from rower one for a *Yes* stroke in Figure 5.1 and a *No* stroke in Figure 5.2.

### ***Analysis***

To determine the association between rower's *Yes* and *No* strokes and boat speed, an intra-individual analysis was adopted. The average boat speed for each individual nominated stroke was compared to the average of the speed of the three previous strokes and a percentage difference between these two values was established (Millar, Oldham, Renshaw, & Hopkins, 2014). The method of comparing the current boat strokes speed with the previous three strokes was chosen as it gave the lowest standard error of the estimate when compared to the SEE of the previous one through to nine strokes (Millar et al., 2014).

To compare the effect on performance of the four different catch measures, the standardised mean difference for each rower's four catch measures was calculated by dividing the difference between the *Yes* and *No* stroke means by the average of the perceived *Yes* and *No* stroke standard deviations. This calculation gave a measure of within-subject standard deviation between each rower's four catch measures in time (ms).

To compare rower *Yes* and *No* judgments to the pitch, the smallest worthwhile difference was established for each individual rower, by taking the mean difference divided by the between-subject SD for the standardised mean difference scores for PitchT. Magnitudes of standardised effects were calculated and described using a Cohen scale with 0.2 as the smallest worthwhile effect size (Cohen, 1988)

## Results

Of the total 273 strokes, 148 Yes strokes and 125 No strokes were analysed. There was an average of  $18.5 \pm 5.8$  Yes strokes per rower and  $15.6 \pm 4.0$  No strokes per rower. Table 5.1 demonstrates that rowers were correct about performance judgments in relation to boat speed with Yes nominated strokes 0.18 to 1.01% quicker than the average of the previous three strokes. No strokes were on average 0.37 to 0.85% slower.

Table 5.1: Individual Rowers Mean, Standard Deviation (SD) and  $\pm 95\%$  Confidence Limits in Boat Speed (%) from the Average of the Previous Three Strokes for Yes and No Strokes.

	Rowers							
	1**	2**	3*	4**	5	6**	7**	8*
Mean & SD								
Yes	0.84 $\pm$ 0.87	0.18 $\pm$ 0.59	0.43 $\pm$ 0.65	0.60 $\pm$ 0.94	0.64 $\pm$ 1.5	0.45 $\pm$ 0.68	1.01 $\pm$ 1.6	0.73 $\pm$ 0.56
No	-0.40 $\pm$ 0.86	-0.60 $\pm$ 0.96	-0.38 $\pm$ 1.3	-0.64 $\pm$ 1.2	-0.59 $\pm$ 1.6	-0.37 $\pm$ 0.74	-0.85 $\pm$ 1.4	-0.56 $\pm$ 1.3
Confidence limits $\pm 95\%$								
Yes	0.38	0.24	0.27	0.51	0.68	0.30	1.00	0.76
No	0.42	0.57	0.70	0.53	1.03	0.42	0.65	0.70

\*\* Difference between means significant at the  $p \leq 0.01$  level and \* significant at the  $p \leq 0.05$  level.

Table 5.2: Within-subject Mean, Standard Deviation (SD) and  $\pm 95\%$  Confidence Limits of the Standardised Mean Differences Between Yes and No Strokes for the Four Catch Measures.

Catch Measure	Mean (SD)	Confidence limits $\pm 95\%$
pkFT	-0.02 (0.31)	$\pm 0.22$
AccelT	0.03 (0.34)	$\pm 0.23$
PLFT	0.08 (0.36)	$\pm 0.25$
PitchT	0.59 (0.33)	$\pm 0.23$

Out of all of the measures, the time (milliseconds) at which maximum boat pitch velocity occurred had the greatest effect upon boat speed, while the other three measures only had a trivial to small effects on performance. Table 5.3 showed the greatest SMD between Yes and No strokes; in essence showing that there was a ‘real difference’ between Yes rated and No judged strokes.

For all eight rowers, *Pitch* was found to have the greatest effect on rowing performance of the four catch measures. *Pitch* (both time and angle values) had the largest standardised mean difference between Yes and No strokes, with a small to moderate effect on performance. The other three measures only had trivial to small effects on performance. Table 5.3 illustrates the mean, standard deviation (SD) and smallest worthwhile difference (SWD) of the PitchDeg and PitchT for Yes compared with No strokes for each rower.

Table 5.3. Mean, standard deviation (SD) and smallest worthwhile difference (SWD) between Yes and No strokes for the PitchDeg (°) and PitchT (ms) for each rower

	Rowers							
	1	2	3	4	5	6	7	8
<i>PitchDeg (°)</i>								
Yes	56.1(4.4)	72.4(6.0)	64.8(7.5)	66.0(3.7)	65.3(3.1)	55.2(2.5)	46.5(2.6)	50.5(3.0)
No	59.0(4.6)	74.7(2.2)	66.8(7.1)	66.8(3.6)	68.7(6.6)	56.1(2.2)	48.8(3.2)	54.1(2.5)
SWD	0.86	0.81	1.46	0.74	0.96	0.47	0.58	0.77
<i>PitchT (ms)</i>								
Yes	704(38)	746(42)	688(58)	723(35)	735(36)	648(39)	554(25)	616(44)
No	723(48)	775(37)	726(41)	732(33)	745(47)	675(15)	560(39)	663(45)
SWD	8.6	7.9	9.9	6.7	8.3	4.6	4.4	11.2

For all eight rowers, *Pitch* occurred sooner in the *Yes* strokes than in the *No* strokes (see Table 5.3). The oar angle and time differences all had smallest worthwhile differences greater than 0.2 for each rower. Despite some individual differences in *Pitch* values, which in part were due to the range of male/female and heavy/lightweight rowers in this subject group, all rowers reached the *Pitch* earlier on *Yes* than *No* strokes. A visual representation of the relationship between *Pitch* (ms) and boat speed (ms) is presented in Figure 5.3.

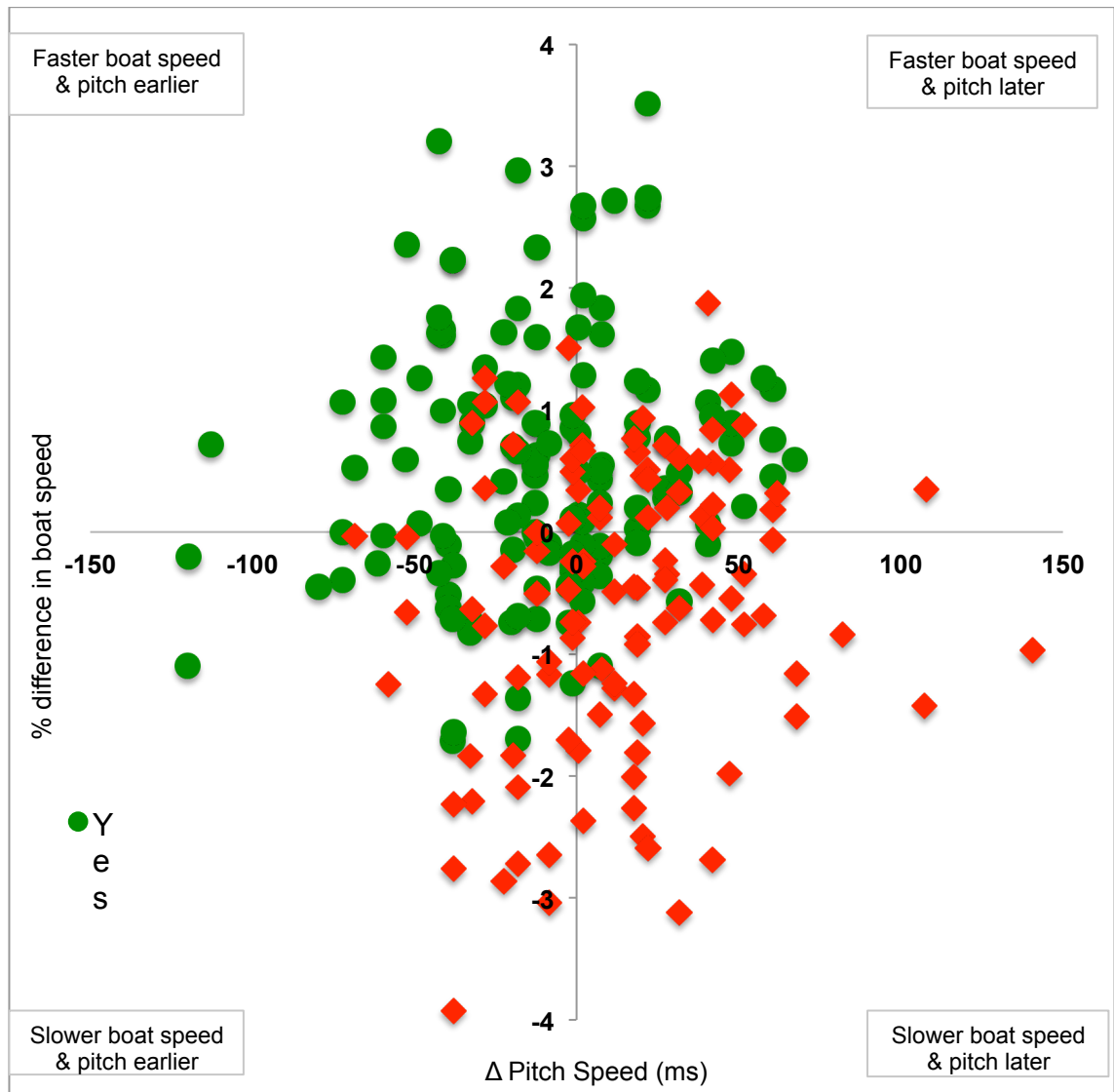


Figure 5.3: A visual representation of the relationship between boat speed and the Maximum boat pitch speed. % change in boat speed from the average of the previous three strokes and the delta difference between the average Maximum boat pitch speed for each subject and the actual value for a particular stroke.

Figure 5.3 represents the percentage change in boat speed from the average of the previous three strokes and the delta difference between the average maximum boat pitch speed for each subject and the actual value for a particular stroke. A quicker boat speed compared with the previous three strokes is displayed in the top half of the graph, while a slower boat speed is represented in the bottom half. A quicker time to *Pitch* is on the left side and a slower time on the right side. A greater number of *Yes* strokes were situated in the top left quadrant, which represents a quicker boat speed and a quicker time to *Pitch*. The bottom right quadrant represents a slower boat speed and a longer time to *Pitch*. *Yes* strokes were more likely to be faster and achieve a quicker time to *Pitch* than *No* strokes.

## **Discussion and Implications**

A well-timed catch is not easy to define, and rowers appreciate the difficulty of learning to time the entry of their oar into the moving water. A simple explanation of the catch is the time taken from when the oar first enters the water, until it is fully covered or “locked” into the water (McBride, 2005). However, despite this simple explanation, it does not describe how to accomplish an ideal catch. While there is discrepancy amongst rowing coaches about how the best catch is achieved (Kleshnev & Baker, 2007), there is little disagreement that good timing of the catch can minimise boat speed losses (McBride, 2005). Therefore, this study aimed to use rowers’ subjective performance based judgments to compare the four biomechanical measures of catch efficiency and establish if athlete perceptions of slower or faster boat speeds related the quality of a specific catch in a stroke.

In a sport like rowing where speed is crucial to performance, it is important to consider rower’s perceptions in relation to boat speed. This study established that strokes which rowers considered to be successful, (*Yes* strokes) were qualitatively faster than unsuccessful strokes. The smallest worthwhile change in performance time over 2000-m at race pace for international rowers to effect a change in medal prospects is 0.3% (Smith & Hopkins, 2011), which equates to a distance of 6 m over a 2000-m race. The rowers, except for rower two, were above this 0.3% threshold for smallest worthwhile effect; therefore identification of a *Yes* stroke had a meaningful difference for boat performance. While this study was performed at 20 spm and not

at race pace, it is assumed that coaches and rowers would welcome boat speed improvements of 0.5 to 1%; which over a 10km training row equates to travelling 50-m to 100-m further. Like most cyclical sports, if you miss-time one section of the stroke, you are likely to continue to do so stroke after stroke and this can have a compounding effect on performance.

This study demonstrated how accurately rowers made performance judgements while rowing, without relying on boat speed instrumentation. This may be due to the unique and developing knowledge which emerges from extended practice (Davids, 2012; Kidman & Hanrahan, 2011). This invites an interesting observation; given rowers' are accurate informants about performance, is the cost and time required for extra feedback from boat instrumentation equipment required? This thought might provide coaches with alternative methods for assisting the development of their rowers. Further research that confirms the utility of the pitch variables identified here, and especially prospective studies addressing the value of different kinds of feedback in improving rowing performance are needed.

This study aimed to provide answers to biomechanists, rowers and coaches about which of the four catch measures to use, based on performance effect sizes. The clear result was that the pitch of the boat is the best measure to use. The poor result for the three existing catch measures (i.e. pkFT, PLFT and AccelIT) are consistent with findings of elite scullers (Coker, 2010). In particular, Coker (2010) found inconsistent results when comparing the three established catch measures (not Pitch) to boat speed, as no one catch measure proved to be a strong indicator of performance. The result associated with reaching 30% of peak pin force and catch slip is because the rower can start applying force to the oar while it is changing direction and this can give a quicker value, without achieving a quicker acceleration time (Kleshnev, 2002a).

Rower's who identified Yes strokes all achieved an earlier Pitch value than No judged strokes. Reaching Pitch quickly allows the boat to return to a more neutral position in the water earlier, and thus have less drag acting on the boat (Sinclair et al., 2009). The rower's ability to reach Pitch earlier was associated with enhanced boat speed, as rower judged Yes strokes were faster than No strokes. This study has provided some explanation of the situation expert rowers described in the qualitative study by Millar et al., (2013), where they mentioned feelings of

heavy and lightness when they are performing. For example, *“it will feel a bit easier and a lot lighter at the catch when you have it right. You feel the boat pick up and it is a lot smoother.”* And *“it feels extremely heavy if you don’t have it right. It feels really light and easy if you have it right”*. These lighter and easier comments about the catch could be associated with reaching Pitch earlier and therefore reducing the drag on the boat sooner; which could give an easier feel to the stroke.

The catch is technically completed near the start of the drive phase of the stroke; however, the *Pitch* measure occurs during the middle of the drive phase, which is when the blade is perpendicular to the boat. While it could be argued that this is not the catch, as the time period is ~500-700 ms after the catch, achieving a quicker *Pitch* appears to be the result of a successful catch, rather than occurring at the physical time of the catch. This timing explanation matches qualitative comments by expert rowers; for example *“You can see how fast the stern lifts out of the water when you are catching it right, and you know if it dips too far down you are killing the boat”* (Millar et al., 2013). This quote demonstrates the importance of lifting the stern quickly by achieving *Pitch* early.

While detailed biomechanical measures like positive acceleration and PowerLine angle are available in some high performance environments, it might be that these are better suited for post-collection analysis. Other measures like *Pitch*, which can be identified by expert rowers, could be used on a daily basis to assist on-water performance decisions. A possible solution for, coaches could be to ask rowers to self-judge their catch and count the frequency of *Yes* to *No* ratings to see what improvement in the ratio may occur over time. With less experienced rowers, the rower could identify a perceived successful catch and confirm this with their coach, before continuing on with counting the frequency of *Yes* and *No* rated strokes. Alternatively, if the coach has access to a boat instrumentation system, then periodic measurement of *Pitch* could help determine changes in performance improvement. Training rowers to take notice of boat pitch movement, and the velocity of the movement, could help to improve performance of the catch efficiency.

## **Conclusion**

Athlete's subjective judgment about their performance like pitch may be useful for performance monitoring. With the increase of on-water boat instrumentation available like PowerLine™, consideration needs to be made about the value of its use for feedback to rowers. This study presented an alternative useful method for quantifying the catch to those previously established from boat instrumentation. In particular the use of boat pitch data and achieving *Pitch* earlier in the drive phase of the stroke may be the most valuable. While speed is still an essential indicator of performance, it may be more accurately perceived by our sample of advanced rowers than other biomechanical catch variables.

## ***Limitations***

Potential limitations in our study relate to data capture, analysis and the question put to the rowers. In our study, strokes were effectively considered independently of context; that is they were not analysed relative to previous or subsequent stroke behaviour. A more evolved analysis would examine the relationships within successive strokes. With this in mind antecedents of catch behaviour such as the approach also warrant inclusion in future models. The question posed to the rowers for identifying successful strokes may have been interpreted as a judgment of speed or stroke quality. Ideally, one or the other should be considered but not both at the same time. Nevertheless, the current approach was sufficient to determine differences between efficiency estimators and was supported by boat speed data. A concluding limitation is the small sample of a rather homogeneous set of advance rowers and that the results should be confirmed in other samples of advanced rowers.

## ***Acknowledgements***

Thank you to the rowers for their time and involvement in this study, and to Dr Jennie Coker for providing insight into her doctoral work with the PowerLine™ force gate system.

## CHAPTER 6

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### DISCUSSION AND CONCLUSIONS

The objective of this thesis has been to expand knowledge regarding what makes a rowing boat go fast and, specifically, the role of timing in high-performance rowing. An ecological dynamics approach was taken towards understanding successful performance as a relationship between the rower, the boat and the environment. As a result; the following questions were addressed in this thesis via four separate studies:

- 1) What determines success in rowing and how is timing achieved and controlled?
- 2) Is what looks right for coaches the same as what feels right for rowers, and do they agree?
- 3) What is the role of perceptual information in successful catch timing and is there a relationship between the boat and rowers' speed?
- 4) How do existing biomechanical measures of the catch compare with a new rower-generated catch measure?

These questions were answered through interviews with expert rowers and coaches, a triangulation study of rower-coach agreement compared with boat speed, an investigation of velocity matching between the rower and the boat's speed and a comparison study of established catch measures and a new proposed measure.

This chapter is split into three sections. The first explains key theoretical implications and increases in knowledge due to this thesis and reflects on the thesis methodology. Second, due to the applied nature of this thesis, there is a summary of the four studies completed in the format of a report, with an applied research focus back to key stakeholders (i.e. Rowing New Zealand). The concluding section covers limitations and delimitations placed on the research along with suggestions for future investigations.

## **Thesis Contribution to Increasing the Body of Knowledge**

This section outlines the main theoretical findings arising from Chapters 2–5 of this thesis and explains how they relate to the literature and in what way the body of knowledge has been enhanced.

### ***Interpersonal coordination***

The traditional view is that interpersonal coordination is strengthened via vision of the other performer. While it was found that rowers aim to achieve interpersonal coordination in two-person boats, they did not adopt this strategy of simply watching the person in front of them; instead, rowers have developed a novel method of using perceptual information from the boat and water, in order to achieve interpersonal coordination. Qualitative data in Chapter 2 suggested that expert rowers attune to extrapersonal invariants like visual water speed information as a primary resource in order to achieve skilled interpersonal coordination, thus extrapersonal coordination. Consequently, when both rowers (in two-person boats) can attune to this extrapersonal information, they can achieve interpersonal coordination. Therefore, this thesis has indirectly supported the contention of Schmidt et al. (2011) that coordination may be facilitated through means other than direct visual perception. However, vision still provided information that indirectly contributed to coordination through the perception of visual regulation. Achieving interpersonal coordination through means other than direct perception of extrapersonal information was an important finding in Chapter 2 that has not previously been demonstrated in the literature.

Successful interpersonal coordination has been previously demonstrated via informational linkages between people (e.g. two people in rocking chairs with vision of each other), or through mechanical linkages between objects sharing a base of support. This thesis has provided a real-world example of interpersonal coordination occurring via a combination of mechanical and informational linkages.

### ***Interceptive tasks***

Chapter 4 revealed that, comparable to other dynamic interceptive tasks like fly ball catching, success in rowing corresponded to matching of rower and boat speed during the recovery period of the rowing stroke. This strategy explained the phenomenon of what experts describe

as “rowing with the boat”, by velocity matching between the rower and the boat. Specifically, rowers were able to cancel out the rate of change in boat speed by varying their approach speed during the recovery period of the rowing stroke. This strategy allowed little or no change in the rate of optic flow and conserved perceptual constancy.

In addition, the rower made early adjustments to his/her speed on the approach to the catch, in order to couple to the boat’s speed for longer, which continued right to the point of temporal interception. It seems rowers were able to attune to affordances provided by the rower–environment relationship – specifically, the water passing the boat – in order to couple earlier and maintain this coupling until the catch. While the ontogenic task demands of rowing seem quite complex, it appears that a simple and parsimonious mechanism of speed matching underlines the control of this task.

### ***Behavioural dynamics***

A successful catch in rowing, comparable to other successful interceptive tasks or avoidance actions, requires the performer to be in the right place at the right time. However, the catch in rowing is more complex, as it requires careful temporal interception between an unsighted oar under the control of the rower, and the water. In this respect, high-performance rowing can be considered a real-world example of Warren’s (2006) behavioural dynamics model, where the temporal interception of the catch appears to be a self-organising process that emerges as a consequence of the interaction between the rower and the boat over a given time period. These interactions will vary from stroke to stroke, based on the interaction of the individual (e.g. fatigue), environment (e.g. wind conditions) and task goal (e.g. racing or training pace). Therefore, the skill of the rower is to explore actions that create stable movement solutions and, through this exploration process, to discover energy-efficient movements or ones that limit energy losses. An energetically optimal outcome depends on the rower–environment system requirements and what the situation affords for action, i.e. the exact timing depends on the individual, boat and water conditions on each stroke. Therefore, this process cannot be prescribed by internal or external structures, but rather is dependent of the rower–environment interaction. Chapter 4’s findings revealed that the rower appears to exploit this relationship by adjusting his/her oar angle velocity early in order to maintain a coupling between rower and boat

speed for longer, while delaying the change in boat pitch drop, which would slow them down more quickly.

### ***Psychophysics***

Rowers' successful use of *in situ* performance-based judgements as reported in Chapters 3, 4 and 5 highlighted how accurate performers are about their own performance. The results are similar to those found by Borg (1970), which led to the development of a psychophysical scale measure to physiological responses to exercise. The ability to distinguish between physical states was expanded on in Chapter 4 and 5; where rowers were required to identify whether a movement was successful. Using rowers' performance-based judgements between their own identify successful (*Yes*) or unsuccessful (*No*) strokes was a novel approach, yet a highly task-appropriate solution to studying *in situ* expert movements. Traditional study of skilled movements has compared novice and expert performance (e.g. Abernethy & Russell, 1987; Araujo et al., 2005; Bian & Schempp, 2004; Carr, Starkes, MacMahon, & Beilock, 2002; Nash & Sproule, 2011), which has, unsurprisingly, generally established the expert as a "better" performer. However, given the qualitative statements by expert rowers (in Chapter 2) and their confidence about knowing when a movement was successful, it was appropriate to test this claim when analysing performance. This thesis has established that among high-level performers, there appear to be perceptible movement differences that performers can identify better than their coach.

Chapters 3 and 4 both examined rowers' self-identified *Yes* strokes, either on the recovery or the drive phase of the rowing stroke. It was established that rowers' own performance-based judgements were correct and they were able to detect small changes in speed through perceptual attunement to higher order invariants, like the speed of the water moving past the boat. While boat performance instrumentation can be accurate when measuring a single variable and calibrated correctly for stable weather conditions, this instrumentation is not designed to measure complex multivariate movements. Consequently, what is good and what is fast may not amount to the same thing. This point was supported by the findings in these chapters, which showed that skilled performers have the ability to make judgements based on

previous experience and in varying conditions. This ability makes them an invaluable informant about their own performance.

### ***Rowing-specific knowledge***

This thesis has revealed that successful timing is achieved through connecting the rowers' movements to those of the boat, not just through coordinating with each other as previously thought. This finding is significant not only for future research on how to improve timing, but also on a practical level for rowers and coaches. For example, coaches will need support in confronting the challenge of coaching a rower to use key timing information from the rowing boat when they themselves are in a separate and markedly different boat (i.e. in a speedboat). These findings also highlight possible learning effects for the use of rowing ergometers, as rowers complete large training volumes on rowing machines. This now raises the question about their use, in particular, how they might engage the rower in seeking out self-organising solutions to this timing problem, which is linked to the boat's movements, not to ergometers (which do not move).

Experts, in this thesis, referred to vertical boat movement information as a key perceptual source that acted as an affordance for action. In particular, stern movements of the boat, which may be a form of looming, or source of haptic information, were considered to be important. In addition, it was established that achieving maximum boat pitch velocity early was a more accurate measure of a successful catch than the measures previously established in the literature. Therefore, boat pitch information during the drive phase of the stroke appeared to be a valuable performance measure, and achieving maximum boat pitch velocity early allowed a faster boat speed to be achieved. The value of boat pitch information was also found to be associated with successful performances in the recovery phase of the rowing stroke. A delayed drop in the boat pitch occurred when rowers were able to couple their speed to that of the boat towards the catch, which allowed them to maintain a faster boat speed. This coupling to boat speed has now provided a quantifiable way of identifying what experts term "rowing with the boat".

## Reflection on Methodological Approach

The methodological approach to this thesis generally helped with the task of answering the key questions of this thesis, but at times proved challenging. Because it addressed the broad key question of “what makes a rowing boat go fast” rather than focusing on testing a piece of theory from the outset, the direction of this thesis emerged from the interaction between the researcher, the experts and the questions. Such a broad question was addressed through a considered, well-structured approach that continued on from others who have studied skill-based questions and then focused on the theory to answer the question. For example, the Mashburn task for analysing flying (Lewis, McAllister, & Adams, 1951) considered the task first and then identified the theory needed to explore the task.

While improvements in performance-based technology and equipment have advantages for both performers and sports scientists, such a focus has also created the problem of producing a large number of primary and derived variables from which to choose. Which one(s) to consider was Kelso’s “inspired guess” or choosing problem (Kelso, 1995). If a strict reductionist approach was taken, then this would see multiple relationships examined in an eliminative fashion, and risk patterns emerging due to chance. The problem of which multiple variables to analyse, and consequently which one(s) to choose, was difficult in Chapter 4 due to the interesting combinations and conclusions that could be made. However, reference to the qualitative data proved to be critical at this point, as it ensured that only those variables that the experts identified – i.e. speed matching between the rower and the boat – were considered.

An applied focus to the research problem has meant that this thesis examined knowledge in several theoretical areas, rather than studying a single theoretical problem. For example, interpersonal coordination, behavioural dynamics, interceptive tasks, psychophysics and biomechanical measures in rowing were all covered. Moving between different and often large theoretical bodies of knowledge has been a challenging task. However, on reflection, it has led to some significant rewards as it allowed key questions of this thesis, which emerged from the expert interviews, to be answered. While different theoretical areas have been extended in this thesis, the focus has remained well grounded in its overarching theoretical approach, which was an ecological dynamics perspective.

## REFLECTION ON PRACTICAL APPLICATIONS

### Timing in Rowing – What Makes a Boat Go Fast?

#### ***Background***

Past literature in the area of successful rowing performance has tended to have a biomechanical focus on the performance – either of the rower (e.g. Barrett & Manning, 2004), who is often studied on a rowing machine (e.g. Ritchie, 2008) or of the boat (e.g. Hill & Fahrig, 2009; Kleshnev, 2007) – but attention to the relationship between the two has been limited. Jennifer Coker's (2010) PhD thesis extended this knowledge by considering rower characteristics and on-water performance. Her thesis revealed that while stroke power and stroke length are important predictors of performance, they have no direct relationship with boat velocity. This invites the question: if it is not stroke power or stroke length, what does impact on performance and achieve the smallest worthwhile gains at the highest level? Based on results equivalent to the winning of the Men's double at the London Olympics (Figure 1.1), and the researcher's experience as a national rowing coach, the answer appeared to lie in the skill of the individual rower. Although it has been suggested that timing between rowers is important, as it may impact on the drag of the boat (e.g. Baudouin & Hawkins, 2002), it seems that research in this area of rowing has not been pursued. Consequently there remains a lack of reported information about timing in high-performance rowing boats and what makes a boat go fast; which was the core question of this thesis.

#### ***Approach to the question: what makes a boat go fast?***

The methodological approach to this thesis drew on an ecological viewpoint, which emphasises how movement is underpinned by a reciprocal relationship between the rower and the environment (Turvey & Shaw, 1999). The important point is that rowers cannot be understood without reference to their particular environments, as the specifics of a high-performance rowing environment constrain what actions the rower takes and, conversely, the actions that the rower takes shape the environment (Warren, 2006). Nine Olympic-level rowers were interviewed at the start of this thesis. Four Olympic-level coaches were also interviewed as, although performers (i.e. rowers) are traditionally considered to directly interact with the performance

environment, coaches significantly influence the learning environment (Araujo et al., 2006; Davids, 2012) and have considerable experience and knowledge (Côté et al., 2007). Expert knowledge, especially from coaches, emerges from trying and testing ideas over many years both in practice and, more importantly, in competition at the highest level. Therefore the ideas experts express are well established, and invaluable to understanding performance. This purposeful approach to understanding expert knowledge, from those performing at the highest level, has been central to the progression of this thesis and the ideas it has explored. In essence, this thesis has expanded on key ideas and beliefs that New Zealand Olympic rowers and coaches hold about timing.

### ***1. The importance of timing and how this is achieved – expert knowledge***

Interviews with nine Olympic rowers and four expert coaches established that interpersonal coordination, or timing/technique as they referred to it, is fundamental to high-performance success. Coaches were also quick to emphasise the importance of boat speed to performance. Nevertheless, the timing between the rowers and the boat was explained as the underlying mechanism for achieving boat speed. That is, expert rowers are able to create environments (e.g. coordinating with the boat) that they can exploit (Seifert et al., 2010). This view of success contrasts with the frequently reported perspective that emphasises the importance of rowers' physical characteristics (e.g. Barrett & Manning, 2004; Bechard et al., 2009; Kerr et al., 2007; Lawton et al., 2013). In contrast to more traditional views of rowing performance (e.g. Barrett & Manning, 2004), neither rowers nor coaches made specific mention of stroke length and power. This does not imply that these aspects are unimportant, but rather suggests that they are most probably a prerequisite to expert performance rather than the focus of it (see Figure 6.1).

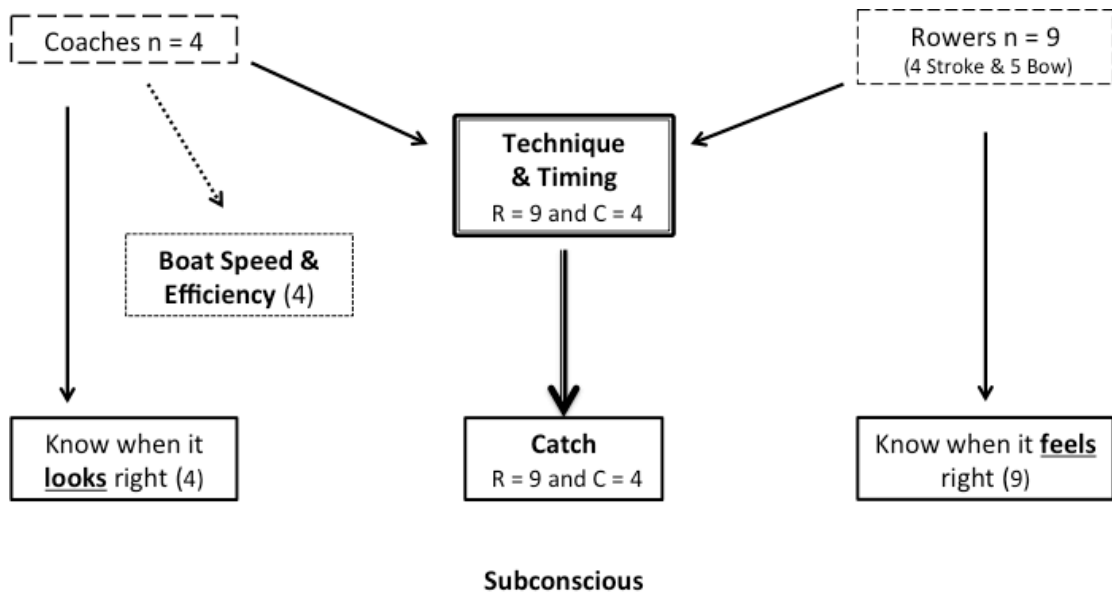


Figure 6.1: Critical factors to success in high-performance rowing

Figure 6.1 highlights the shared viewpoints about the importance of timing, but both coaches and rowers had some difficulty in explicitly explaining successful timing (e.g. see “subconscious”). It is not uncommon for expert performers, such as high-level rowers who perform actions without required conscious control, to find it difficult to describe a well-performed skill. However, both rowers and coaches were confident in their knowledge of successful performance, and claimed they knew what successful timing was, and when it was “right”. In particular, coaches were confident in their ability to use specific information from the movement patterns combined with their effects on the boat/rower/water environment to detect successful performance. Similarly, rowers were able to attune to key boat/rower/water information to successfully monitor and time their own movements. This claim that both expert groups know when a performance is “right” invites key questions like: is what is viewed as “right” by one group seen in the same way by the other? And is “right” as they describe it – i.e. fast? These two questions are answered later in this chapter.

The advantage of interviews with experts was that it permitted a deeper understanding of not only the meaning of timing but also how this is achieved in high-performance rowing. While the emphasis on timing is not surprising in the context of expert rowing, it is surprising with reference to the existing theory about interpersonal coordination. This thesis revealed that

successful timing was achieved through connecting the rowers' movements to those of the boats (see the coordination model in Figure 6.2), whereas existing rowing literature has reported successful timing as the connection of rowers' movements together (e.g. Baca & Kornfeind, 2008; Hill, 2002; Kleshnev, 2008). An expert rower explains the importance of the boat to successful timing in this way: *"I think timing was everything, but it is more important to be in time with the boat"*. This quote not only highlights the importance of interpersonal coordination, but also goes some way to explain how it is achieved, which fundamentally is between the rower and the boat or "rowing with the boat" as rowers often referred to it. In Figure 6.2, the coordination model depicts the complex interpersonal coordination relationship in two-person rowing boats. Bow seat rowers identified multiple information sources available to them. They used visual information about the rower in front of them and the boat/water information; specifically, optical flow information about the water moving past the boat in relation to the rower in front of them. In contrast, stroke seat rowers had less information available to them, but again did use optical flow and boat looming information (the end of the boat moving up and down).

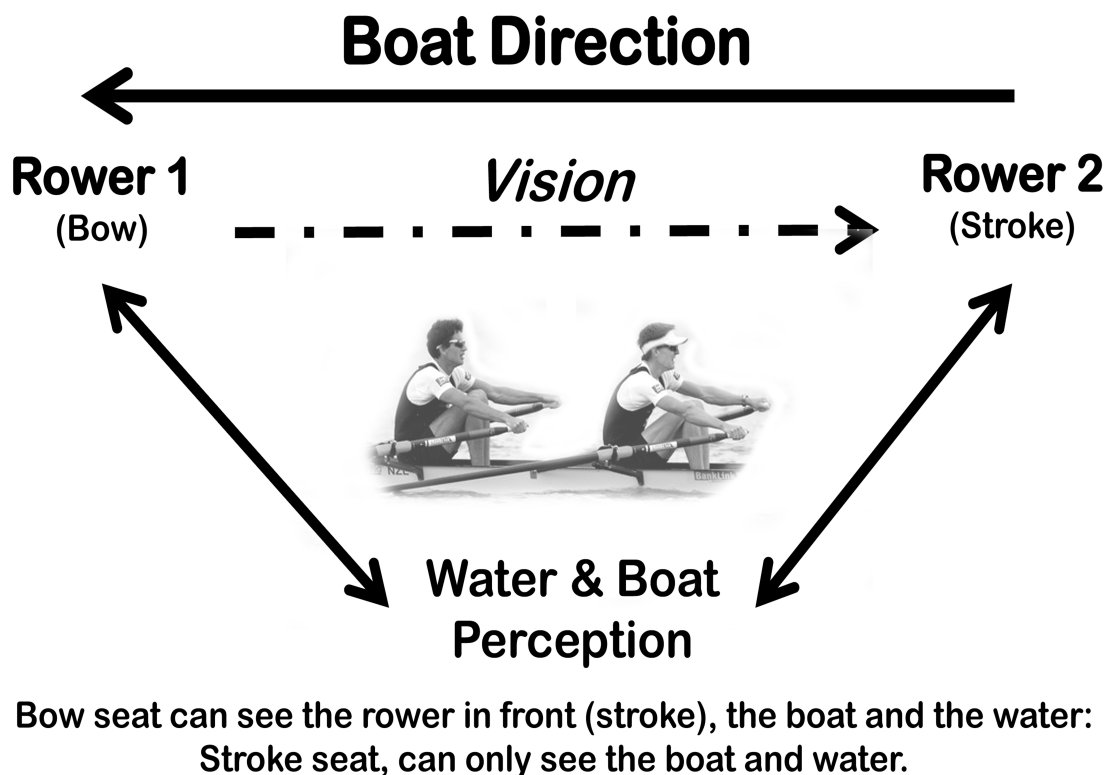


Figure 6.2: Coordination model

The key conclusion here was that, regardless of which seat the rower performs in, timing is influenced by the accurate detection of key information from the boat and water relationship. Therefore, in order to examine the relationship between the boat and rower; further investigations with single scullers were conducted. This decision was made in order to remove other factors influencing performance so that the study could focus on how “rowing with the boat” or extrapersonal coordination occurs. In addition to understanding the importance of timing, a further aim was to determine if one particular part of the stroke had a greater influence on successful timing. Experts were keen to comment that all parts of the stroke are important, but acknowledged that the catch was the key factor contributing to performance above any other point in the stroke (see Figure 6.1 on critical factors). Therefore this thesis had a specific focus on catch timing in successful high-performance rowing boats.

## ***2. Comparison of rower and coach knowledge, and of this knowledge with boat speed***

The claim that both expert rowers and coaches might not be able to exactly describe a movement but would recognise it when they either saw it (as a coach) or knew it (as a rower) proved to be an invaluable assertion to examine. The focus was twofold: first, to examine coach–rower agreement in the performance environment; and second, to compare independent coach and rower decisions about the boat’s performance to actual boat speed.

Eight Regional Performance Centre (RPC) single scullers performed two 10-minute phases of submaximal rowing at 20 spm, while their coach was travelling in a speedboat alongside them. Before the rower and coach went on the water to perform, they were told that about every 30 s during these two 10-minute phases they would be asked to say if that nominated stroke was a *Yes* or *No* stroke. While they were performing on the water, the lead researcher said “Now” late in the drive phase of the rowing stroke, enabling a response from both the rower and coach: either *Yes* the boat was travelling fast because the rower had timed the catch well or *No* the boat was not travelling fast because he/she had not timed the catch well. Rowers wore a wireless microphone that enabled the researcher to record responses, while at the same time

the coach recorded his/her response on a prepared response sheet. Neither the rower nor the coach was able to hear each other's answer at each data collection point, or to find out the actual boat speed during the testing period.

One challenging aspect of this comparison of rower and coach agreement was ascertaining what was "fast". A decision was made that the boat speed for each individual nominated stroke was compared with the average of the speed of the three previous strokes and a percentage difference found between the two values (Millar et al., in review-a). This method of comparing the nominated stroke's speed with the previous three strokes was chosen as it gave the lowest standard error of the estimate, or provided the best predication of performance, when compared with the average of the past one through to nine strokes.

Once the analysis was completed, some noteworthy results were revealed. Disagreements between rowers and coaches were greatest when performance was only marginally faster or slower, with rowers making the greater number of correct judgements. Therefore, it appeared that in coach–rower dyads, expert rowers while performing were better at making performance judgements than coach observers. This greater accuracy may be because rowers have a unique perspective on performance, which provides different information from the information available to the coaches, who are more removed from the direct perceptual information sources available to rowers.

### ***Practical implications***

This thesis has produced a number of key findings that have significant implications for rowing. Specifically:

- 1) Rowers were more accurate than coaches at judging when a performance was successful, relative to the speed of the boat; therefore coaches need to find ways of using rower knowledge as part of their pedagogical practice.
- 2) Coaches cannot identify all the subtle changes in performance; they need the rowers' input and involvement and should be mindful of rower feedback.

- 3) If a coach is unsure about the performance, or cannot confirm it with the athlete, then maybe he/she should consider not saying anything, as the coach is not always likely to be right.

### **3. The role of perceptual information in successful catch timing**

Understanding how perceptual information is used to achieve and maintain extrapersonal coordination in high-performance rowing has been a crucial focus of this thesis. In order to accurately understand how “rowing with the boat” is achieved, it was important to go back and test the experts’ descriptions. Specific aspects for testing were rowers’ descriptions of optic flow from the water, e.g. *“You can pick up the differences in speed by the way the water flows past the boat”*; and also possible looming or haptic information from the stern of the boat in front of them, e.g. *“In stroke seat, you can look at the movement of the boat coming towards them and that water disappearing down the stern; this visual information of the boat is really important”* (coach talking from a rower’s perspective). These explanations helped identify the key variables to analyse in the goal of quantifying “rowing with the boat”, which became the focus in the remaining studies. When interviewed, the Olympic experts talked a lot about the approach to the catch, and therefore the analysis in this study considered the approach and oar placement at the catch.

The previous quote about the speed of the water and the common comment on aiming to “row with the boat” created the basis for examining potential speed matching between the rower and boat, which is similar to other interceptive tasks, e.g. catching a ball on the run, known as fly ball catching. When studying other common interceptive or avoidance tasks, the solution appears to be related to changes in optic flow (e.g. Michaels & Oudejans, 1992; Rozendaal & van Soest, 2003). Specifically a performer adjusts his/her approach speed towards an object in order to maintain a particular speed for himself/herself and an object to be intercepted/avoided. For instance, the rower keeps his/her oar angle speed the same as the boat’s speed approaching the catch.

Given the accuracy of the rowers in identifying their own successful performance, the same on-water performance testing approach as in the previous study (2) was used, but this time only

rower judgements were obtained. Additionally, only the recovery section of the stroke was analysed – specifically from when the oars were perpendicular to the boat “square-off” up to the point of furthest reach (the catch). Chapter 4 considered the following key questions:

- 1) Do top-level rowers use the same speed matching approach for a successful catch in rowing as those catching a fly ball?
- 2) Is success characterised by coupling to speed and, by implication, to optic flow?
- 3) Is a successful catch economical and efficient?

Results revealed that these high-performance rowers did use the strategy of matching their speed to that of the boat on the recovery phase. In looking for an explanation of how this tight coupling between perception and action was maintained up to the point of interception (the catch), an analysis was undertaken to determine when the rower started to adjust his/her oar angle velocity prior to the catch. This analysis provided some clear and noteworthy observations in line with other interceptive task results. Essentially, successful *Yes* strokes were signposted by an earlier adjustment of oar angle velocity (the rower’s speed) than *No* strokes. These results showed that successful strokes appear to be the result of the rower detecting changes in the speed of the boat earlier and adjusting his/her speed, in order to achieve a longer matching of rower and boat speed on the approach to the catch. Unsuccessful *No* strokes were ones where the rower began to slow his/her approach speed late into the catch and did not match his/her speed to that of the boat for as long. Consequently, accurate attunement to boat speed through optic flow information appears key to successful speed matching between the rower and the boat into the catch.

Expert rowers and coaches both referred to boat pitch information as a key perceptual information source in successful timing. A descriptive analysis of the pitch movements of the stern in relation to the *Yes* and *No* strokes on the recovery of the stroke was completed. Results revealed that once again expert knowledge is right, in that for successful *Yes* strokes the drop in the stern occurred later or closer to the catch than it did for *No* strokes. That is, on the recovery, the boat remained in a more neutral state for longer i.e. with less drag acting on the boat for longer with *Yes* strokes than *No* strokes. For *Yes* strokes the drop in the stern or boat pitch was between 20 and 70 ms later than *No* strokes.

The final analysis of this study focused on the recovery and involved obtaining a measure of boat speed, in order to compare *Yes* and *No* strokes. Essentially, the research question was focused on the outcome of *Yes* and *No* strokes and asked, did *Yes* strokes have a faster boat speed on the recovery? This was established by calculating the time taken from “square-off” to the catch, divided by the time taken to the catch. This measure would allow a comparison between strokes to see if successful strokes achieved a faster boat speed on the recovery at 20 spm. The results revealed that successful strokes had between 0.3–4.4% faster boat speed on the recovery than unsuccessful strokes. It is worth noting that changes in boat speed of more than 0.3% represent the smallest worthwhile change in performance time over 2000 m for international rowers to effect a change in medal prospects (Smith & Hopkins, 2012).

### ***Practical implications***

The key practical implications of this study are that:

- 1) The accurate detection of changes in boat speed on the recovery is important in order to match rower and boat speed. This skill needs to be developed in rowers.
- 2) The rower’s ability to match his/her speed to the boat and also maintain a level boat for as long as possible is associated with successful strokes.
- 3) How do rowers know if they are getting better? Effective forms of feedback are needed and should not only be provided by external information sources.
- 4) The current practice of rowers completing large volumes of training on rowing machines should be considered, as it has been shown not to engage the rower in seeking out self-organising solutions to this timing problem.
- 5) Thought is needed about how rowing in larger boats (fours and eights) improves the skill of timing. Maybe rowers need more time in smaller boats as part of their development.
- 6) Rowers are accurate informants about boat speed and performance on the recovery, and finding ways of utilising this knowledge is desirable.

#### **4. Comparing a new rower-determined measure of the catch with existing biomechanical measures**

As outlined earlier, knowledge about successful rowing has predominately had a biomechanical focus (e.g. Bechard et al., 2009; Coker, 2010; Doyle et al., 2010; Hill & Fahrig, 2009), and a number of techniques have been identified for defining and measuring an effective catch. Three existing methods include: the time taken to achieve 30% of peak pin force (Kleshnev, 1999); when the boat reaches positive acceleration (Coker, 2010); and an arbitrary catch slip value automatically generated by a biomechanics feedback instrument for rowing such as PowerLine™. A fourth and new method for catch efficiency was identified in this thesis, which is to establish the timing of rowers' *maximum boat pitch velocity* – namely the time from the minimum gate angle (i.e. the catch) to the point at which maximum boat pitch velocity (cm/s) was achieved. This measure was established on the basis of the interviews with Olympic rowers and coaches. For example, one of the rowers stated, “*I would always be watching the stern for the pick up, rather than letting it sink and jump*”. One method of measuring this “pick up”, as the rowers call it, is to calculate how quickly after the catch rowers are able to achieve *maximum boat pitch velocity*. Given the challenge for rowers and coaches in assessing performance, four completely different catch measures were compared with rowers' self-identified successful Yes strokes. Therefore, this study used the same method for data collection with RPC rowers as the previous study. The time from maximum oar angle (the catch) to the time during the drive (where one of the four above catch measures was achieved) was used for the analysis for this study i.e. the time from the catch to 30% of peak pin force, positive boat acceleration, PowerLine™ catch slip value and *maximum boat pitch velocity*.

Of particular interest in this study were the following two questions:

- 1) Would Yes strokes be faster than No athlete-judged strokes during the drive?
- 2) What measure of catch efficiency has the strongest prediction of performance?

It was established that strokes that rowers considered to be successful were faster than unsuccessful strokes. Yes strokes were on average 0.6% faster on the drive than the mean of the previous three strokes. While this difference may appear small, 0.3% is the smallest worthwhile change in performance time over 2000 m at race pace for international rowers to

effect a change in medal prospects (Smith & Hopkins, 2011). All RPC rowers, except one, were above this 0.3% threshold for smallest worthwhile effect; therefore identification of a Yes stroke made a meaningful difference to boat performance.

The purpose of this study was to provide answers to rowers and coaches about which of the four catch measures has the greatest effect on performance. The clear result was that the pitch of the boat is the best measure to use i.e. *maximum boat pitch velocity*. The poor results for the three existing catch measures (i.e. the time from the catch to 30% of peak pin force, positive boat acceleration, PowerLine™ catch slip value) are consistent with findings on elite scullers by (Coker, 2010). In particular, Coker (2010) found inconsistent results when comparing the three established catch measures (not *maximum boat pitch velocity*) with boat speed, as no one catch measure alone proved to be a strong indicator of performance.

In conjunction with expert comments and the measure of *maximum boat pitch velocity*, another aim was to establish how the timing of *maximum boat pitch velocity* changed from Yes to No strokes. Rowers who identified Yes strokes all achieved an earlier *maximum boat pitch velocity* value in those strokes than in No judged strokes. Quickly reaching *maximum boat pitch velocity* allows the boat to return to a more neutral position in the water earlier, resulting in less drag acting on the boat (Sinclair et al., 2009).

It is acknowledged that the catch is technically completed near the start of the drive phase of the stroke; however, the *maximum boat pitch velocity* measure occurs during the middle of the drive phase, which is when the blade is perpendicular to the boat. While it could be argued that this is not the catch, as the time period is ~500 ms after the catch, achieving a quicker *maximum boat pitch velocity* appears to be the result of a successful catch, rather than occurring at the physical time of the catch. This timing explanation matches qualitative comments by expert rowers; for example “*You can see how fast the stern lifts out of the water when you are catching it right, and you know if it dips too far down you are killing the boat*”. This quote demonstrates the importance of lifting the stern quickly by achieving *maximum boat pitch velocity* early.

### ***Practical implications***

This study produced the following points for practitioners to consider:

- 1) Rowers can make accurate performance judgements while rowing, without relying on boat speed instrumentation. This invites an interesting observation: given rowers are accurate informants about performance, is extra feedback from boat instrumentation equipment always required or in fact necessary at all?
- 2) Gaining feedback from the rower is important, especially as he/she has access to greater perceptual information than a coach does based on his/her view from a speedboat or land.
- 3) Training rowers to take notice of boat pitch movement and the velocity of the movement could help to improve the catch efficiency.
- 4) Coaches need to help develop the perceptual skills of the rower, so the rower is more able to coach himself/herself, especially as he/she often trains for long distances on his/her own.
- 5) While speed is still an essential indicator of performance, its limited usefulness in judging performance in some water and weather conditions means a viable alternative could be to rely on the rower to judge speed.
- 6) If there is access to a boat instrumentation system, then periodic measurement of *maximum boat pitch velocity* could help to determine changes in performance improvement.

## Thesis Limitations

- 1) The primary limitation of the research was the difficulty of gaining access to elite (national senior) and sub-elite (Regional Performance Centre) rowers. As the research was aimed at identifying “ideal” performance in many facets, high-quality rowers were needed. Due to the demanding schedules of rowers at elite and sub-elite levels, gaining access to a large number of rowers at any time throughout the four years of this research (regardless of training season) was challenging.
- 2) Sub-elite rowers were used for all on-water studies of performance. It is clear from literature that elite athletes are more consistent in training, and produce a faster boat speed than sub-elite and novice. Therefore, elite and novice athletes cannot expect to have the same results as the sub-elite rowers recruited for these on-water studies.
- 3) In Chapter 3 the duration of the coach-rower relationship differed between subjects and this could be claimed to have an impact on the success of the coaches’ judgements of performance.
- 4) The exact transition point between the recovery and the drive in rowing, known as the catch is problematic to delineate (See Chapter 5 for further explanation). The velocity matching and catch comparison studies (Chapters 4 and 5 respectively) were based on performance data on either the drive or recovery. A definite point between these two phases of the rowing stroke was required, which was called the catch, but it could be argued this was not the true catch, as defined by some (e.g. Kleshnev & Baker, 2007; Richardson, 2005). Therefore a consistent measure of the maximum oar angle point was used to define the catch for these studies.
- 5) It could be argued that the uni-directional nature of the force measure provided by PowerLine™, and the fact that it measures pin force rather than actual propulsive force at the blade, were a limitation to the comparisons of catch measures (Chapter 5). However, the user-friendly nature of PowerLine™ and the fact it is the system of choice for Rowing New Zealand mean that using the system for analysis is necessary when working with these athletes and feeding back to rowers and coaches.

## **Delimitations**

- 1) Only expert rowers (defined as rowers who have competed at the Olympics or World Championships) and expert coaches (defined as those who have coached crews at the Olympics) were invited to participate in the qualitative study (Chapter 2).
- 2) Only sub-elite single scullers (defined as those who are in the Rowing New Zealand talent development programme and have competed for New Zealand as either an International Junior or International U23 rower) and their coaches were invited to participate in the triangulation study of boat, rower and coach performance data (Chapter 3).
- 3) Only sub-elite single scullers (defined as those who are in the Rowing New Zealand talent development programme and have competed for New Zealand as either an International Junior or International U23 rower) were invited to participate in the velocity matching and catch comparison studies (Chapters 4 and 5 respectively).
- 4) No scullers with any current injuries that could have inhibited their performance were invited to participate.
- 5) For the velocity matching and catch comparison studies (i.e. Chapters 4 and 5) the standard error of the predicted  $y$ -value for each  $x$  in the regression (STEYX) for each individually nominated Yes or No stroke was calculated. The mean and standard deviation STEYX value for each group of strokes in a block of 10 minutes was determined, and any stroke that fell outside the range of two standard deviations from the mean was excluded from the data set

## **Future Directions**

Now that this thesis has provided new knowledge about what factors make a boat go fast, the next logical and fundamental step is to discover what makes them go even faster. With the understanding from this thesis that successful high-performance rowing can only be considered at the rower–environment level of analysis, it is important that any future study preserves the relationship between the rower and the boat. To that end, one of the first steps in future *in situ* studies is to consider both the recovery and drive of the stroke in the analysis of successful

performance. Consideration of successive strokes is also required to further understand this dynamic relationship, as movements and speed generated on one stroke will influence what is afforded to the rower on the subsequent stroke(s).

While accurate on-water analysis of performers in their natural environments will remain a challenge for researchers, the methods employed in this thesis have provided the basis for further research. In particular, future studies will need to examine and possibility manipulate how vision is used to match boat to rower speed. This examination will provide answers to questions about what section(s) of the stroke might afford particular movements to emerge rather than others, i.e. occluding vision during different parts of the recovery and the impact on coupling.

This applied research was originally designed to answer key questions about timing in rowing, with the aim of assisting in the development of rowers to achieve successful interpersonal coordination. Therefore, further experimental research from an ecological dynamics perspective is needed. On the basis of early descriptive studies in this thesis, there is a need to consider how pitch movements in the boat might be more detectable by the rowers. This could possibly be achieved by either changing the weight of the boat or having a moving weight in the boat to heighten changes in pitch.

## **Conclusion**

The relationship between the rower and the boat is dynamic and constantly changing. Therefore, the skill of the rower is to be attuned to key perceptual variables that provide crucial affordances for action. It appears that the high-performance rowers in this thesis have developed the ability to use key specifying information from the boat–water relationship which allows them to reach faster boat speeds not only during the drive of the stroke, but more importantly on the recovery when they are not adding propulsive force to the boat.

The emergent strategy of rowers to achieve interpersonal coordination is to couple their actions to those of the boat. In particular, coupling was strongest during the final approach to the catch, when rowers adjusted their speed to match the boat's as early as possible. The coupling of

rower movement speed to the boat also allows the boat to travel further before the boat pitches up and changes the drag on the boat. This approach seems to be an energy-conserving solution to the dynamic relationship between the boat, the water and the rower, as well as a simple and parsimonious solution to a complex movement problem.

**This thesis can explain what makes high-performance boats go fast; however, now we need to know what makes them go faster and get more crews performing like this.**



Figure 6.3 Winning crew

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## APPENDIX 1

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### AUT ETHICS COMMITTEE APPROVAL – 19TH MAY 2009



#### MEMORANDUM

#### AUCKLAND UNIVERSITY OF TECHNOLOGY ETHICS COMMITTEE (AUTEC)

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To: Tony Oldham

From: **Madeline Banda** Executive Secretary, AUTEC

Date: 19 May 2009

Subject: Ethics Application Number 09/104 **Establishing the key timing and coordination points required for successful performances in multiple rower boats.**

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Dear Tony

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by a subcommittee of the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 7 May 2009 and that the acting Executive Secretary has approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 15 June 2009.

Your ethics application is approved for a period of three years until 19 May 2012.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- 4) A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/about/ethics>. When necessary this form may also be used to request an extension of the approval at least one month prior to its expiry on 19 May 2012;
- 5) A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/about/ethics>. This report is to be submitted either when the approval expires on 19 May 2012 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEK is notified of any adverse events or if the research does not commence. AUTEK approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEK grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this. Also, if your research is undertaken within a jurisdiction outside New Zealand, you will need to make the arrangements necessary to meet the legal and ethical requirements that apply within that jurisdiction.

When communicating with us about this application, we ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact Charles Grinter, Ethics Coordinator, by email at [charles.grinter@aut.ac.nz](mailto:charles.grinter@aut.ac.nz) or by telephone on 921 9999 at extension 8860.

On behalf of the AUTEK and myself, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely



Madeline Banda (**Executive Secretary**)

**Auckland University of Technology Ethics Committee**

Cc: Sarah-Kate Miller [skmillar@aut.ac.nz](mailto:skmillar@aut.ac.nz), AUTEK Faculty Representative, Health and Environmental Sciences

## APPENDIX 2

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### PARTICIPANT INFORMATION SHEET



**DATE INFORMATION SHEET PRODUCED:** 19TH MAY 2009

**Project Title:** Establishing the key timing and coordination points required for successful performances in multiple rower boats

**Your Invitation:**

You are invited as an expert in the area of rowing to participate in a research project. This project aims to establish from elite rowing coaches and athletes, their perceptions of the key timing and coordination points required for successful performances in multiple rower boats.

This project is being undertaken by Sarah-Kate Millar, a PhD candidate from the Faculty of Health and Environmental Sciences. Participation in the project will involve attendance at an interview with the researcher for 20-25 minutes. Your participation in this project is completely voluntary and you may withdraw at any stage of the study without any adverse consequences.

Written and oral reports and other material coming out of this project will present only aggregate data and information. Quotes from this interview may be made part of the final research report. Under no circumstances will your responses, name or identifying characteristics be included in this report.

**The purpose of this research:**

Sarah-Kate Millar is undertaking this research for her PhD thesis at AUT-University. She anticipates that the results will have a wide benefit to the community of rowing, in particular in the area of rower and coach development. Sarah-Kate hopes to publish the findings at

conferences and in academic and professional journals. The results of this study will form the basis of both oral and written presentations in the area of motor behaviour and in the development of coaching.

### **How were you chosen for this invitation?**

You have been invited to participate in this research, as you are either an elite rowing coach or athlete who has competed at the World Championship or Olympic level with a crew boat. Your name was recommended by your peers.

### **What will happen in this research?**

If you agree to take part, you will be asked to;

- Sign a participation consent form and to be invited for a brief interview
- Complete a semi-structured interview at your hometown or on the phone. The questions to be asked in the interview are included with this information sheet.
- The semi-structured interview is envisaged to last between 20 and 25 minutes. The interview will be recorded via audiotape and note taking. This will be analysed by common themes.

### **What are the discomforts and risks?**

Any discomfort or risk is unlikely. However, the interview will required the participants to reflect on their current rowing or coaching practice.

### **How will these discomforts and risks be alleviated?**

You don't need to answer any questions that you don't wish to and are free to withdraw at any time. You will have the opportunity to review the transcript of discussions and amend or withdraw comments.

### **What are the benefits?**

By taking part, you will help to increase knowledge of the area of key coordination points of athlete timings in crew boats. In particular it is envisaged that a good practice model will be

presented to New Zealand Rowing and wider rowing audiences in terms of athletes learning the key timing points for successful crew performances. This information will then lead onto further studies around the idea of how can you coach these timing points to rowers?

**How will my privacy be protected?**

Your personal details will be kept confidential in the course of this study. That is your name or identifying characteristics will not be included in any reports or data recorded from this study. Written and oral reports that come from this study will look at aggregate data and information. Quotes from this interview may be made part of the final research report. Under no circumstances will your responses, name or identifying characteristics be included with those excerpts. If you have any concerns in this regard we can provide examples where this has been done previously. Your interview data will be held on a password-protected computer held by Sarah-Kate Millar.

**What are the costs of participating in this research?**

There are no monetary costs involved in the participation of this research and it is expected that participation in this research will require no more than 20 to 25 minutes of your time.

**What opportunity do I have to consider this invitation?**

You are requested to consider and respond to this invitation within the next two weeks. You are welcome to ask any questions that you may have; please direct them to Sarah-Kate Millar (contact details below)

**How do I agree to participate in this research?**

If you agree to participate please return the attached consent form. You will be contacted to arrange an agreed time and place for the interview.

**Will I receive feedback on the results of this research?**

It is anticipated that a summary of the findings will be available within 12 months of completion of the project and copies of this will be made available if requested. The results from this project will also be presented to New Zealand Rowing.

**What do I do if I have concerns about this research?**

- Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Name: Dr Tony Oldham

Email: toldham@aut.ac.nz

Phone: 09 921 9999 ext 7057

- Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, *madeline.banda@aut.ac.nz*, 921 9999 ext 8044.

**Whom do I contact for further information about this research?**

**RESEARCHER CONTACT DETAILS:**

Name: Sarah-Kate Millar

Email: sarahkate.millar@aut.ac.nz

Phone: 09 921 9999 ext 7667

**PROJECT SUPERVISOR CONTACT DETAILS:**

Name: Dr Tony Oldham

Email: toldham@aut.ac.nz

Phone: 09 921 9999 ext 7057

Approved by the Auckland University of Technology Ethics Committee on 19<sup>th</sup> May 2009. AUTEK Reference number 09/104

## APPENDIX 3

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### PARTICIPANT CONSENT FORM



*Project title:*     **Establishing the key timing and coordination points required for successful performances in multiple rower boats**

*Project Supervisor:*     **Dr Tony Oldham**

*Researcher:*             **Sarah-Kate Millar**

- I have read and understood the information provided about this research project in the Information Sheet dated 19<sup>th</sup> May 2009
- I have had an opportunity to ask questions and to have them answered.
- I understand that notes will be taken during the interviews and that they will also be audio-taped and transcribed.
- I understand that I may withdraw myself or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant information including tapes and transcripts, or parts thereof, will be destroyed.
- I agree to take part in this research.
- I agree to my comments being reported anonymously in the findings of this study.

Yes  No

- I wish to receive a copy of the thematic analysis of my interview; in order to make a comment on the phone or in writing about the extent to which I agree to disagree with the themes drawn from the interview (please tick one):

Yes  No

- I wish to receive a copy of the report from the research (please tick one):

Yes  No

Participant's signature:.....

Participant's name:.....

Participant's Contact Details (postal address for correspondence about study)

Date: .....

*Approved by the Auckland University of Technology Ethics Committee the 19<sup>th</sup> May 2009. AUTEK Reference number 09/104*

## APPENDIX 4

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### EXPERT ROWERS - INTERVIEW PROTOCOL & PLANNED QUESTIONS

*What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed.*

Interviewer: \_\_\_\_\_

Interviewee: \_\_\_\_\_ Gender: \_\_\_\_\_

Date & Time: \_\_\_\_\_ Location: \_\_\_\_\_

Experience Level: \_\_\_\_\_

#### **PROTOCOL**

My name is Sarah-Kate Millar. I am working on an approved research study at AUT – University involving the understanding of what expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed. The study will involve elite rowers from New Zealand.

Thank you for your willingness to participate in this research project. Have you read the information provided to you, entitled “participates information”? Before we begin the interview, I would like to reassure you that this interview will be confidential and the tape and transcripts available only to my research supervisor and me.

Do you voluntarily agree to participate in this interview?

Do you mind if I record the interview?

(if yes) If there is anything you don't want me to record; just let me know and I will turn off the recorder.

Written and oral reports and other material coming out of this study will present only aggregate data and information. Excerpts of this interview may be made part of the final research report. Under no circumstances will your responses, name or identifying characteristics be included in this report. Do you have any questions I can answer for you before we begin?

Is it all right for me to turn on the recorder now?

### **Interview questions**

***What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed.***

### **Perceptual info used**

What perceptual information do rowers rely on when performing successfully (or less successfully)?

1. What determines if you are performing well?
2. How do you know?
3. What perceptual information do you rely on when performing successfully?
4. What perceptual information do you rely on when performing less successfully?
5. Can you tell me more about a particular time when ...(example from something the participant has said)

### **Hierarchy of info used**

What information do rowers find is the most constant and reliant when they are performing?

6. Do you have some information that you have more confidence in that other information about indicating how well you are performing?
7. What is this?
8. Which is more or less reliant for you?
9. Do you have a critical point/information source that you most rely on? (Other than the stop watch)

### **How do you change? What tells you?**

When rowers need to make a change in performance, what perceptual information do they employ to make this decision and how do they judge the outcome of this change?

10. How do you know when you need to make a change in your performance?
11. Is this the only way that you know? (Expand more)

12. How did you learn to rely on this information source?
13. What other ways have you found to learn to gain information about how well you are performing (from the boat/environment)
14. Do you use different information for making different changes?
15. What are these?
16. What part of the stroke do you think rowers need to be able to control/change well themselves?
17. Why do you think this part?
18. How do you learn to make that change? What tells you?

### **Use of the boat/environment to regulate movement**

How does the boat and environment impact of their ability to make changes to their performance?

19. What role do you think the boat and/or environment has in informing your movements?
20. Why do you think this?
21. How did you learn this?
22. What has been a big influence in how you learnt this?
23. What reinforces to you to keep using this info about your performance?
24. If it is not going well and you can not use the above listed info, what else do you rely on to tell you about your performance?
25. Why this source of info?

### **Additional Questions**

26. In a 200m race, how many different phases are there?
27. The literature has talked about there being two; acceleration and steady state – what do you think of this idea?

NB: \* is a possible question to help probe for further information of clarification on an idea.

## APPENDIX 5

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### AUT ETHICS COMMITTEE APPROVAL – 21ST JULY 2011



#### MEMORANDUM

#### AUCKLAND UNIVERSITY OF TECHNOLOGY ETHICS COMMITTEE (AUTEC)

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To: Tony Oldham

From: **Charles Grinter** Ethics Coordinator

Date: 21 July 2011

Subject: Ethics Application Number 11/161 **What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed.**

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Dear Tony

Thank you for providing written evidence as requested. I am pleased to advise that it satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC) at their meeting on 27 June 2011 and I have approved your ethics application. This delegated approval is made in accordance with section 5.3.2.3 of AUTEC's *Applying for Ethics Approval: Guidelines and Procedures* and is subject to endorsement at AUTEC's meeting on 8 August 2011.

Your ethics application is approved for a period of three years until 20 July 2014.

I advise that as part of the ethics approval process, you are required to submit the following to AUTEC:

- 1) A brief annual progress report using form EA2, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. When necessary this form may also

be used to request an extension of the approval at least one month prior to its expiry on 20 July 2014;

- 2) A brief report on the status of the project using form EA3, which is available online through <http://www.aut.ac.nz/research/research-ethics/ethics>. This report is to be submitted either when the approval expires on 20 July 2014 or on completion of the project, whichever comes sooner;

It is a condition of approval that AUTEK is notified of any adverse events or if the research does not commence. AUTEK approval needs to be sought for any alteration to the research, including any alteration of or addition to any documents that are provided to participants. You are reminded that, as applicant, you are responsible for ensuring that research undertaken under this approval occurs within the parameters outlined in the approved application.

Please note that AUTEK grants ethical approval only. If you require management approval from an institution or organisation for your research, then you will need to make the arrangements necessary to obtain this.

When communicating with us about this application, I ask that you use the application number and study title to enable us to provide you with prompt service. Should you have any further enquiries regarding this matter, you are welcome to contact me by email at [ethics@aut.ac.nz](mailto:ethics@aut.ac.nz) or by telephone on 921 9999 at extension 8860.

On behalf of AUTEK, I wish you success with your research and look forward to reading about it in your reports.

Yours sincerely

Charles Grinter

On behalf of Dr Rosemary Godbold and Madeline Banda **Executive Secretary**

**Auckland University of Technology Ethics Committee**

Cc: Sarah-Kate Millar [smillar@aut.ac.nz](mailto:smillar@aut.ac.nz), Patria Hume

## APPENDIX 6

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### PARTICIPANT (ROWER) INFORMATION SHEET



DATE INFORMATION SHEET PRODUCED: JUNE 2011

**Project Title:** What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources utilised.

**Your Invitation:**

You are invited as an expert coach to participate in a research project. This project is aiming to answer two questions;

1. Do expert rowers and coaches agree on successful rowing instances?
2. What perceptual information do you (as a rower) employ while you are rowing?

Sarah-Kate Millar, a PhD candidate from the Faculty of Health and Environmental Sciences at AUT University, is undertaking this project. Participation in this project will involve you completing two 10-minute phases of rowing at 20 strokes per minute on the water in a single scull. Once these two phases of rowing are completed and you are back on the bank; you will watch a video of yourself rowing and answer a series of questions about what perceptual information you used while performing. Perceptual information being; sight, sound, smell, taste, and touch. Your participation in this project is completely voluntary and you may withdraw at any stage of the study without any adverse consequences.

Written and oral reports and other conclusions from this project will present only aggregate data and information. Under no circumstances will your responses, name or identifying characteristics be included in this report.

**The purpose of this research:**

Sarah-Kate Millar is undertaking this research for her PhD thesis at AUT-University. She anticipates that the results will have a wide benefit to the community of rowing, in particular in the area of rower skill improvement and coach development. Sarah-Kate hopes to publish the findings at conferences and in academic and professional journals. The results of this study will form the basis of both oral and written presentations in the area of motor behaviour and in the development of coaching.

**How were you chosen for this invitation?**

You have been invited to participate in this research, as you are either an elite, U23 or in the Regional Performance Centre (RPC) and associated with Rowing New Zealand. Your name was recommended by either Rowing New Zealand or your RPC.

**What will happen in this research?**

If you agree to take part, you will be asked to;

- Sign a participation consent form  
On the water
- You will be wearing a wireless microphone on your top; this has the ability to pick up your comments while you are rowing. This microphone has a single headphone attached to it so you can hear the researcher on the water.
- You will wear a small head camera on your hat (this will be attached for you and removed at the end of the session).
- Your boat will be fitted with a force gate analysis system; this will record boat performance data during the two phases. This will be fitted onto the boat for you before the session starts and removed after the session. This will not impact your performance.
- Complete two 10 minute sessions of sub - maximal rowing at 20 spm on the water in a single scull. You will have 5-8 minutes rest between each phase. You will have 20-30 minutes to warm up before you start the first 10-minute phase.

- Approximately every 30 seconds (during the 10 minute phase) the researcher will ask you how well the boat is going now? This is when you will be required to provide a yes or no decision about how well you feel the boat is travelling at that point in time. (see below)

2-point rating scale to identify how fast and well-timed your rowing is around the catch.

- Yes – boat is going very well (good timing at the catch)
- No – the boat is not going very well (poor timing at the catch)

At the same time the coach will also make their decision verbally in the coach boat (which is travelling beside you). Neither you nor the coach will be able to hear each other's answer at each data collection point. You will also not know the actual speed of the boat during the session.

Off the water

After you have completed your two 10 minute sessions of maximal rowing at 20 spm and finished rowing for that session and had 10 -15 minutes to warm down, you will;

- Go to the rowing club where your head camera video footage from your row will be projected onto a large screen in front of you.
- You will row on a row perfect rowing machine while footage of the two 10 minute phases will be replayed in front of you. You will re-row the two 10 minute phases; in time with the video footage, but not at maximum effort.
- During this video and while you are rowing, you will be asked a series of open-ended questions about what perceptual information you used to provide yourself with feedback about successful and non-successful rowing throughout the whole 10 minute phase, not just the period of rowing when the researcher asked you on the water.
- The rowing session on the water and the interview on the bank are anticipated to take no more than 120 - 140 minutes of your time. The interview will be recorded via audiotape and note taking. This will be analysed by common themes.

**What are the discomforts and risks?**

It is not anticipated that there is any ethical risks to you during the on-water data collection. You will be requested to perform a physical activity (two x 10 mins) that you would normally spend 80% - 85% of your training time completing. During the off-water interview you will be required to reflect on your current rowing and this is not considered to cause you any discomfort or risk. You can withdraw from the data collection and interview process at anytime without harm.

**How will these discomforts and risks be alleviated?**

You free to withdraw at any time. You will have the opportunity to review the transcript of discussions and amend or withdraw comments.

**What are the benefits?**

By taking part, you will help to increase knowledge of the area of how rowers use perceptual information to inform them about successful rowing performances. In particular it is envisaged that a good practice model will be presented to New Zealand Rowing and wider rowing audiences in terms of athletes learning the key timing points for successful performances. This information will then lead onto further studies around the idea of how can you coach these timing points to rowers?

**How will my privacy be protected?**

Your personal details will be kept confidential in the course of this study. Your name or any identifying characteristics will not be included in any reports or data recorded from this study. Written and oral reports that come from this study will look at aggregate data and information. If you have any concerns in this regard we can provide examples where this has been done previously. Your on-water data will be held on a password-protected computer held by Sarah-Kate Millar.

**What are the costs of participating in this research?**

There are no monetary costs involved in the participation of this research and it is expected that participation in this research will require no more than 70 minutes of your time.

### **What opportunity do I have to consider this invitation?**

You are requested to consider and respond to this invitation within the next two weeks. You are welcome to ask any questions that you may have; please direct them to Sarah-Kate Millar (contact details below)

### **How do I agree to participate in this research?**

If you agree to participate please return the attached consent form. You will be contacted to arrange an agreed time and place for the interview.

### **Will I receive feedback on the results of this research?**

Your verbal contributions on the water, plus the boat speed data can be made available to you within 2 weeks of the collection if requested. Only if the rower gives their permission, can you see their results in conjunction with yours. The rower can only see your results if you give permission for this.

It is anticipated that a summary of the findings will be available within 18-36 months of completion of the project and copies of this will be made available if requested. The results from this project will also be presented to New Zealand Rowing.

### **What do I do if I have concerns about this research?**

- Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Name: Dr Tony Oldham

Email: [toldham@aut.ac.nz](mailto:toldham@aut.ac.nz)

Phone: 09 921 9999 ext 7057

- Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, [madeline.banda@aut.ac.nz](mailto:madeline.banda@aut.ac.nz), 921 9999 ext 8044.

**Whom do I contact for further information about this research?**

**Researcher contact details:**

Name: Sarah-Kate Millar

Email: sarahkate.millar@aut.ac.nz

Phone: 09 921 9999 ext 7667

**Project supervisor contact details:**

Name: Dr Tony Oldham

Email: toldham@aut.ac.nz

Phone: 09 921 9999 ext 7057

**Approved by the Auckland University of Technology Ethics Committee on 21/7/2011 AUTEK Reference number**

11/161

## APPENDIX 7

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### PARTICIPANT (COACH) INFORMATION SHEET



DATE INFORMATION SHEET PRODUCED: JUNE 2011

**Project Title:** What expert rowers and coaches agree is on successful rowing instances; the perceptual information sources utilised.

**Your Invitation:**

You are invited as an expert coach to participate in a research project. This project is aiming to answer two questions;

1. Do expert rowers and coaches agree on successful rowing instances?
2. What perceptual information do rowers employ while they are rowing?

This project is being undertaken by Sarah-Kate Millar, a PhD candidate from the Faculty of Health and Environmental Sciences. Participation in the project will involve you observing a single scull rower that you normally coach and commenting about how well you think they are performing. This information will then be compared with how well they feel they are performing and what speed the boat is travelling.

Written and oral reports and other conclusions from this project will present only aggregate data and information. Under no circumstances will your responses, name or identifying characteristics be included in this report.

**The purpose of this research:**

Sarah-Kate Millar is undertaking this research for her PhD thesis at AUT-University. She anticipates that the results will have a wide benefit to the community of rowing, in particular in the area of rower skill improvement and coach development. Sarah-Kate hopes to publish the

findings at conferences and in academic and professional journals. The results of this study will form the basis of both oral and written presentations in the area of motor behaviour and in the development of coaching.

### **How were you chosen for this invitation?**

You have been invited to participate in this research, as you are a coach of an elite, U23 or Regional Performance Centre (RPC) single scull rower. Your name was recommended by Rowing New Zealand.

### **What will happen in this research?**

If you agree to take part, you will be asked to;

- 1) Sign a participation consent form
- 2) On the water
- 3) You will be sitting in the coach boat travelling alongside the rower while they perform two 10-minute sessions of sub - maximal rowing at 20 spm on the water in a single scull.
- 4) Approximately every 30 seconds (during the 10 minute phase) the researcher will ask you how well you think the boat is going at that point in time? This is when you will be required to provide yes or no decision (from looking at the performance) about how well you think the boat is travelling at that point in time. (see below)

#### 2-point rating scale to identify how fast and well-timed the rowing is around the catch.

- Yes – boat is going very well (good timing at the catch)
- No – the boat is not going very well (poor timing at the catch)

At the same time the rower will also make their decision verbally in the rowing boat. A wireless microphone on the rower will record their answer at each data collection point (30 sec interval). Neither you nor the rower will be able to hear each other's answer at each data collection point. You will also not know the actual speed of the boat during the session.

5) Your yes/no decision will be recorded on a clipboard that you will be holding in the coach boat, which will be filming the rower's performance. You will need to write 'Y' or 'N' in the column beside each data collection point (20 in each 10 minute phase).

**What are the discomforts and risks?**

It is not anticipated that there is any ethical risks to you during the on-water data collection. You will be requested to make a yes/no decision about how well you think the rower is performing at a point in time. This is a decision that you would regularly make during your coaching session on the water (often to yourself) and one that is not considered to cause you any discomfort or risk. You can withdraw from the data collection and interview process at anytime without harm.

**How will these discomforts and risks be alleviated?**

You free to withdraw at any time. You will have the opportunity to review the transcript of discussions and amend or withdraw comments.

**What are the benefits?**

By taking part, you will help to increase knowledge of the area of how rowers use perceptual information to inform them about successful rowing performances. In particular it is envisaged that a good practice model will be presented to New Zealand Rowing and wider rowing audiences in terms of athletes learning the key timing points for successful performances. This information will then lead onto further studies around the idea of how can you coach these timing points to rowers?

**How will my privacy be protected?**

Your personal details will be kept confidential in the course of this study. Your name or any identifying characteristics will not be included in any reports or data recorded from this study. Written and oral reports that come from this study will look at aggregate data and information. If you have any concerns in this regard we can provide examples where this has been done previously. Your on-water data will be held on a password-protected computer held by Sarah-Kate Millar.

**What are the costs of participating in this research?**

There are no monetary costs involved in the participation of this research and it is expected that participation in this research will require no more than 70 minutes of your time.

**What opportunity do I have to consider this invitation?**

You are requested to consider and respond to this invitation within the next two weeks. You are welcome to ask any questions that you may have; please direct them to Sarah-Kate Millar (contact details below)

**How do I agree to participate in this research?**

If you agree to participate please return the attached consent form. You will be contacted to arrange an agreed time and place for the interview.

**Will I receive feedback on the results of this research?**

Your verbal contributions on the water, plus the boat speed data can be made available to you within 2 weeks of the collection if requested. Only if the rower gives their permission, can you see their results in conjunction with yours. The rower can only see your results if you give permission for this.

It is anticipated that a summary of the findings will be available within 18-36 months of completion of the project and copies of this will be made available if requested. The results from this project will also be presented to New Zealand Rowing.

**What do I do if I have concerns about this research?**

- Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor:

Name: Dr Tony Oldham

Email: toldham@aut.ac.nz

Phone: 09 921 9999 ext 7057

- Concerns regarding the conduct of the research should be notified to the Executive Secretary, AUTEK, Madeline Banda, *madeline.banda@aut.ac.nz* , 921 9999 ext 8044.

**Whom do I contact for further information about this research?**

**Researcher contact details:**

Name: Sarah-Kate Millar

Email: sarahkate.millar@aut.ac.nz

Phone: 09 921 9999 ext 7667

**Project supervisor contact details:**

Name: Dr Tony Oldham

Email: toldham@aut.ac.nz

Phone: 09 921 9999 ext 7057

**Approved by the Auckland University of Technology Ethics Committee on 21/7/2011 AUTEK Reference number**

11/161

## APPENDIX 8

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### CONSENT FORM (ROWER)



*Project title: What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed*

*Project Supervisor: Dr Tony Oldham*

*Researcher: Sarah-Kate Millar*

- I have read and understood the information provided about this research project in the Information Sheet dated 11<sup>th</sup> June 2011
- I have had an opportunity to ask questions and to have them answered
- I understand that I will row and complete two 10 minute phases of rowing at 20 spm.
- I understand that video footage and boat speed data will be recorded while I am performing on the water
- I understand that notes will be taken during the interviews and that they will also be audiotaped and transcribed
- I understand that I may withdraw myself or any information that I have provided for this project at any time, without being disadvantaged in any way
- If I withdraw, I understand that all relevant information including video footage, audiotapes and transcripts, or parts thereof, will be destroyed
- I agree to my comments being reported anonymously in the findings of this study

Yes  No

I wish to receive a copy of the thematic analysis of my interview; in order to make a comment on the extent to which I agree to disagree with the themes drawn from the interview (please tick one):

Yes  No

I agree to a copy of my rowing performance being available for the coach to see in conjunction with their results (please tick one):

Yes  No

If the coach agrees; I would like to receive a copy of the video clips where both the coach and I thought the boat was going well and the boat speed data also supported this finding (please tick one):

Yes  No

I wish to receive a copy of the report from the research (please tick one):

Yes  No

I agree to take part in this research

Participants signature:.....

Participants name:.....

Participant's Contact Details (postal or email address for correspondence about study)

.....

.....

Date: .....

**Approved by the Auckland University of Technology Ethics Committee on the 21/7/2011.**

**AUTEC Reference number 11/161**

## APPENDIX 9

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### CONSENT FORM (COACH)



*Project title: What expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed*

*Project Supervisor: Dr Tony Oldham*

*Researcher: Sarah-Kate Millar*

- I have read and understood the information provided about this research project in the Information Sheet dated 11<sup>th</sup> June 2011
- I have had an opportunity to ask questions and to have them answered.
- I understand that I may withdraw myself, or any information that I have provided for this project at any time prior to completion of data collection, without being disadvantaged in any way.
- If I withdraw, I understand that all relevant information including audiotapes, or parts thereof, will be destroyed.
- I understand that I will make a yes/no decision about how well the single sculler is performing at approximately 30 seconds intervals during two 10-minute rowing sessions.
- I agree to my comments being reported anonymously in the findings of this study.

Yes  No

I agree to a copy of my comments being available for the single sculler to see in conjunction with their performance results (please tick one):

Yes  No

If the single sculler agrees; I would like to receive a copy of the video clips of where both the single sculler and I thought the boat was going well and the boat speed data also supported this finding (please tick one):

Yes  No

I wish to receive a copy of the report from the research (please tick one):

Yes  No

I agree to take part in this research.

Participants signature:.....

Participant's name:.....

Participant's Contact Details (postal address for correspondence about study)

.....

.....

Date: .....

***Approved by the Auckland University of Technology Ethics Committee the 21/7/2011.***

***AUTEC Reference number 11/161***

## APPENDIX 10

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### EXAMPLE EMAIL TO POTENTIAL PARTICIPANTS

From: Sarah-Kate Millar

To:

Subject: Potential involvement in rowing study

Hello,

My name is Sarah-Kate Millar; your name has been given to me by Rowing New Zealand (RNZ) as an expert rower/coach (delete one). RNZ think because of your experience and skill level that you might be someone who could be interested in being involved in a rowing study?

I am working on an approved research study at AUT – University involving the understanding of what expert rowers and coaches agree is on successful rowing instances; the perceptual information sources employed. I anticipate that the results will have a wide benefit to the community of rowing, in particular in the area of rower skill improvement and coach development.

I have attached an information sheet for you to read about this study. The study is on the water and in your own environment. It involves both the rower and coach at the same time. The time involved in this study is quite small; 70-120 minutes at your training venue over one training session.

I look forward to hearing back from you by XXX about your possible interest in this project. From there we can then start to plan what date/time might suit you best.

Regards,

Sarah-Kate Millar

## APPENDIX 11

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### ON-WATER PROTOCOLS

Safety

Observation

#### **SAFETY:**

Every Association, Club, School, College and University in New Zealand is required to follow the Rowing New Zealand's Water Safety Code (2004), see appendix 9 for a copy. This safety code has clear direction about rowers, coaches, equipment and training.

The researcher will comply with this established safety code. (Including life jackets and standard practices) The on-water requirements of this research fully act in accordance with the safety code. There is no requirement for rowers or coaches to act/ behave in a way that does not support the set safety code. The use of video cameras on the water is a standard practice for rowers and coaches and this does not go against the safety code in any way.

#### **PROTOCOL**

My name is Sarah-Kate Millar. I am working on an approved research study at AUT – University involving the understanding of what expert rowers and coaches agreement is on successful rowing instances; the perceptual information sources employed.

The study will involve elite rowers and coaches from New Zealand.

Thank you for your willingness to participate in this research project. Have you read the information provided to you, entitled "participates information"?

Do you voluntarily agree to participate in this project?

## **Protocol before going on the water**

### With the coach:

- Establish from looking at the club map of the water, what section of water the proposed two data collections will occur at. This is to be done with the rower, coach and researcher together.
- Discuss alternatives to the proposed section of water if an alternative is needed
- Discuss potential hazards on the water at this particular rowing club

### With the Rower:

- Discuss with the coach as well as the selected rower about the section of water where the data collection will occur
- Discuss alternatives to the proposed section of water if an alternative is needed
- Discuss potential hazards on the water at this particular rowing club
- Fit the single scull with the force gate analysis system (complete system checks with analysis system)
- Fit a LED light to the single scull and have it in a position that can be seen from inside and outside the boat (check the 30 seconds timing of this).
- Fit the head camera to the rower's sunglasses or hat. Give the bag with the recording device in to the rower to put around their waist. Check the camera is recording and working correctly)

### *The rowers will be required to:*

- Wear a wireless microphone on their top; this has the ability to pick up their comments while they are rowing.
- Wear a small head camera on their sunglasses or hat (this will be attached and removed at the end of the session).

- Have their boat fitted with a force gate analysis system; this will record boat performance data during the two phases. This will be fitted onto the boat before the session starts and removed after the session. This will not impact their performance.

**OBSERVATION:**

Remind the coach of the on water requirements for the study

- They will be sitting in the coach boat travelling alongside the rower while the rower performs two 10 minute sessions of sub - maximal rowing at 20 spm in a single scull.
- Every 30 seconds (during the 10 minute phase) a LED light will flash in the (rowing) boat and this will be the signal for the coach to provide a yes or no decision (from looking at the performance) about how well the coach thinks the boat is travelling at that point in time. (see below)

*2-point rating scale to identify how fast and well-timed the rowing is around the catch.*

- Yes – boat is going very well (good timing at the catch)
- No – the boat is not going very well (poor timing at the catch)

6)

- Their yes/no decision will be recorded by the video camera in the coach boat, which will be filming the rower's performance.

Remind the rower of the on water requirements for the study

- They will have 20-30 minutes to warm up before they start the first phase. This will be a warm-up the rower and coach set as their standard procedure for each session.
- Complete two 10-minute phases of sub - maximal rowing at 20 spm on the water in a single scull. They will have 5-8 minutes rest between each phase.

- Every 30 seconds (during the 10 minute phase) a LED light will flash in the (rowing) boat and this will be the signal the rower to provide a yes or no decision about how well they feel the boat is travelling at that point in time.

2-point rating scale to identify how fast and well-timed your rowing is around the catch.

- Yes – boat is going very well (good timing at the catch)
  - No – the boat is not going very well (poor timing at the catch)
- 
- That they have time to warm-down before getting off the water to complete their interview on the row-perfect machine.