USING EXPERT KNOWLEDGE TO INFORM MULTIVARIATE ANALYSES

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This paper outlines methods and reasoning that advocate for the use of expert Coach and Athlete knowledge in support of mutivariate analyses in Sport Biomechanincs and related disciplines. It argues that human movement research involving the collection of multiple dependent variables suffers similar problems to other areas of behavioural science, in that models proposed for analyses are inadequately constrained by other data and are vulnerable to a-posteori modification that lacks sound theoretical or evidential justification. An approach is presented where expert accounts of how successful movements are performed are captured and analysed *qualitatively*, in order to present data themes that may be used to identify important events and variables for analyses when *quantitatively* examining movement. This paper argues for the utility of a specific mixed-methods approach to movement research involving multiple dependent variables.

KEYWORDS: multivariate analyses, expert knowledge, mixed-methods.

INTRODUCTION: A feature of Sports Biomechanics over the last few decades has been the ability to collect multiple dependent variables from the same participants and derive further variables via methods such as correlation and calculus. This is exemplified by the range of variables generated in the course of 3D motion analysis. While the abundance of descriptive material may be seen as an asset, researchers are confronted by the problem of extracting meaningful patterns from data which have validity and application in real-world settings. This is a common and widely discussed problem in behavioural science (Breckler, 1990; Fiedler, 2011; Kelso, 1995). Put simply, as the number of variables collected increases the number of potential relationships increase accordingly. This brings with it several problems, the most pressing of which is the ability to distinguish between meaningful and meaningless relationships that may be revealed in the course of statistical analysis. In order to manage this problem, the standard scientific model instructs researchers to base decisions on relevant theory and available data, which is problematic. When pursuing research through observational or representative designs, the relationship between data and theory may be argued to be abstract. For example, a good understanding of Newtonian mechanics will not make it obvious if there is a meaningful relationship between ground reaction force and head position in a given athletic movement; albeit that they might be highly correlated. Equally, taking a strict approach to decision making based on other published data is made difficult by the need to examine each relationship as a separate hypothesis, while providing support for an overarching model. In this case there may not be sufficient available research. Kelso (1995) quite rightly points to the possibility that researchers will need make inspired or intuitive decisions when identifying meaningful relationships. This is risky in that the more data researchers have, the more guesses they get to make. Thus, there is a greater likelihood of presenting relationships that are based more on their knowledge of the data than any valid understanding of the world. In an epistemological sense this might be viewed as the difference between knowing what you are looking for (a relationship) and knowing why you are looking for it (a contextually valid benefit). Furthermore, decisions about hypotheses made by researchers confronting multiple variables beg the question of relevant knowledge of context. While researchers may have experience of the athletic movement being examined, that experience is framed by their own world view which may be of limited generality. Indeed, the argument that skills fit bodies rather than bodies fitting a perfect model of skill, would suggest that most athletic experiences are unique to the performer and by default not generalisable in and of themselves (Davids, Galzier, Araújo, & Bartlett, 2003). These issues are not unique to Biomechanics but are found in several other disciplines that demand multivariate analyses.

THEMES AND MEMES: Important processes employed in the generation of scientific data are, peer review, transparency and the testing of hypotheses where appropriate. These processes, which are selective, elevate scientific knowledge above other forms of knowing. There are however, other ways of knowing and selecting useful knowledge, one of which is particular to the sporting domain. Sport by definition is a competitive and intrinsically selective process. In the course of becoming successful, knowledge possessed by high performing coaches or athletes is regularly tested directly in the domain of interest. Thus, the development of expert sporting knowledge is constantly subject to personal hypothesis testing as well as performance testing. While this knowledge of how to succeed in sport lays firmly in the domain of Folk Science it escapes several common criticisms put to it by virtue of the unique, rigorous way in which it is created. This process may be illustrated and modelled along evolutionary lines using Dawkins's concept of "memes". A meme is defined as a "unit of cultural transmission, or a unit of imitation" (Dawkins, 2006, p.192). Memes are argued to be subject to Darwinian evolutionary mechanisms, therefore a meme pool when subjected to evolutionary pressure will select and retain the "fittest" memes. In the same way, competitive sport is full of ideas and methods regarding how to be successful. The process of competition acts as a selection mechanism eliminating poor ideas and spreading more effective ones. Memes in the strict sense are not the product of trial and error, but imitation facilitated by teaching, reading and observation (Blackmore, 2000). Both coaching and training share similarities with these processes providing opportunities for adaptive (possibly Lamarckian) variation. Regardless, sport as a deliberately selective contest should see the most successful performers, coaches and relevant experts contain memes of value in understanding successful performance. These "memotypes" or units of knowledge are common to experts and adapted to that particular sporting niche. The process of collecting and comparing these memes will not only add to understanding of sporting success but act as a useful heuristic to research.

MIXED METHODS: When viewed as the "fittest", best adapted set of ideas within a given domain, it should be no surprise that the value of expert knowledge is increasingly being recognised throughout Sport Science (Greenwood, Davids, & Renshaw, 2014; Russell & Salmela, 1992). Common methods for acquiring this knowledge in a publishable form, involve the use semi-structured qualitative interviews, from which themes may be drawn. The theming process is inductive in so far as it is data driven and pragmatic in that it aims to capture effective expert knowledge that is common to successful athletes or coaches. Theming may be argued to be analogous to the deliberate profiling of genotypes in order to better understand what contributes to the success of an organism in a given environment. In the case of movement analysis, asking coaches questions regarding which elements of a movement are important in developing expertise, or asking athletes what determines an effective expert movement, should be informative when trying to identify suitable variables or events for detailed analysis. Theming should end in what is termed "thick description" in this context this may be taken to mean elements of analysis are identified along with associated expert reasoning for their inclusion. It worth emphasising, that a critical requirement of this process is eliciting data from *expert* performers. Whether coaches or athletes, what makes the data useful is that it has been tested informally through multiple competitive iterations. While competition as a selective process in sport may lack the structure or transparency of the formal scientific method, it does involve more repeated testing than is commonly found in contemporary sport science. Expert themes then, when triangulated with researcher knowledge and relevant theory/literature, can be used to generate quite specific apriori hypotheses for multivariate analysis. Here, it is also worth noting that while themes (memes) are not subject to standard scientific rigour with respect to how they are generated, they possess a default level of external validity which experimental and quasi-experimental data often lacks. In so far as ideas drawn from practice are being used as part of testable hypotheses results should serve to enhance practice directly. The method as intended, is not like Grounded Theory in that the goal of collecting qualitative data is not explicitly tied to the development of theory per se, but in order to constrain and shape the search for meaningful relationships when confronted with multiple variables.

METHOD IN USE: The approach outlined has been used in practice by Millar and colleagues (Millar, Oldham, & Renshaw, 2013; Millar, Oldham, Hume, & Renshaw, 2015). Initially the research team conducted a study into rowing that qualitatively explored what elite coaches and athletes described as elements contributing to a fast boat in Olympic Double Sculling. Data drawn from interviews were combined with relevant theory and literature to build a model of boat performance that tentatively described how rowers coordinate within a boat for maximum effectiveness. Thick description pointed to the critical role of the “catch” in making a boat go faster, which agreed with other literature drawn from the field. More detailed description also highlighted the concept of “rowing with the boat” and the importance of viewing water going past the boat as part of this process. This was an unexpected finding contrary to initial expectations of the research team. This information was used to argue for a novel concept in coordination termed “extra-personal coordination”. The qualitative data was also used to create and validate a new derived performance variable - Oar Angle Velocity. Subsequently, this variable was successfully employed in a study designed to evaluate which of three catch efficiency measures was best in Single Sculling and to investigate the impact of visually textured surfaces (Fig 1) on sculling performance (Millar & Oldham, 2016; Millar et al., 2015). The concept of extra-personal coordination has since been quantitatively verified in other international research and the methodology highlighted in recent reviews (Balagué, Torrents, Hristovski, & Kelso, 2016; R'Kiouak, Saury, Durand, & Bourbousson, 2017). On the basis of initial published work, it would seem that this mixed method has some applicability and value.

Figure 1: Example of visually textured surface on a rowing boat to better detect water flow.

SUMMARY OF APPROACH:
An outline account of how the approach has been used in published research has been presented along with reasoning and discussion of potential benefits in terms of external validity of studies. The approach:

1. Qualitatively interrogates expert knowledge regarding successful movements.
2. Triangulates qualitative findings with published data/theory and researcher knowledge.
3. Uses triangulated information to develop a performance model.
4. Quantitatively examines functional relationships identified within the model.

CONCLUSION: The origins of this approach lay in the perceived need to constrain research involving the collection of multiple variables while investigating human movement. Methods as commonly employed in the field suffer threats to internal validity relating to a lack of specifying data and poorly contextualised researcher decisions. The proposed mixed method, by combining expert performance data with other conventionally derived data has the potential to address these issues in some part, provided that certain guidelines are met. Furthermore, the method affords the opportunity for research of this type to achieve greater external validity and generality uncommon in more restricted quantitative methods. These advantages need to be weighed against the burden of doing additional data collection and interpretation before commencing quantitative investigation. In order to fully understand and refine this approach, the method needs more widespread use as well as a broader peer review. In light of the current problems around the confirmation of findings this may prove to be a good use of time.

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