BEHAVIOUR CHANGE SCIENCE AND MOBILE TECHNOLOGY IN SPORTS NUTRITION

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INTRODUCTION

The type, timing, and total amounts of food and fluid consumed by an athlete on a daily basis can have a significant impact on their health and performance. Hence, dietary strategies have been developed to reduce injury and illness risks, amplify training adaptations, and to enhance competition performance. Specifically, carefully periodised plans, that recommend adjusting energy, macronutrient and micronutrient intakes, on a day by day and meal by meal basis, inspired by the "fuel for the work required" research, has come to the forefront of sport nutrition[1].

Yet, despite knowing what and when to eat, athletes still struggle to adhere[2-5]. In fact, nutrition knowledge appears to have only a small bearing on an athlete's dietary behaviours[6-7]. Simply put, just because an athlete knows what to do, it doesn't mean they're going to do it. It appears clear that education alone is insufficient to influence change. Instead, multifaceted and theoretically driven behaviour change interventions need to be designed and delivered, where education may be one component of a more comprehensive strategy.

However, designing a successful behaviour change intervention is a complex process. A range of theory and evidence-based tools developed in behavioural science are required, all of which play crucial roles in the development and evaluation of effective interventions[8-10]. The use of these tools has yet to become widespread in sports nutrition where there is a distinct absence of theoretically driven behaviour change interventions reported in the literature[11]. Additionally, and unfortunately, the vast majority of sports nutritionists' lack behaviour change training, limiting their ability to positively influence an athlete's diet[12].

It follows that progress in the field of sports nutrition is being impeded. The almost exclusive research focus on increasing our understanding of biochemistry, physiology and physical performance has resulted in improvements in knowledge, facilitating the development of more robust fuelling, recovery and performance strategies. However, the translation of this knowledge into nutrition behaviours in athletes remains inadequate. Embracing behavioural science to help bridge this gap is now one of the challenges facing sports nutritionists.

In addition to this, COVID-19 has brought many practical challenges to all sectors of industry, and nutrition service provision is no exception. In short, practitioners have moved online. Organisations are looking for cost effective remote solutions rather than onsite presence. As a result, sports nutritionists are no longer limited by location as they digitally deliver their services globally via various platforms. This

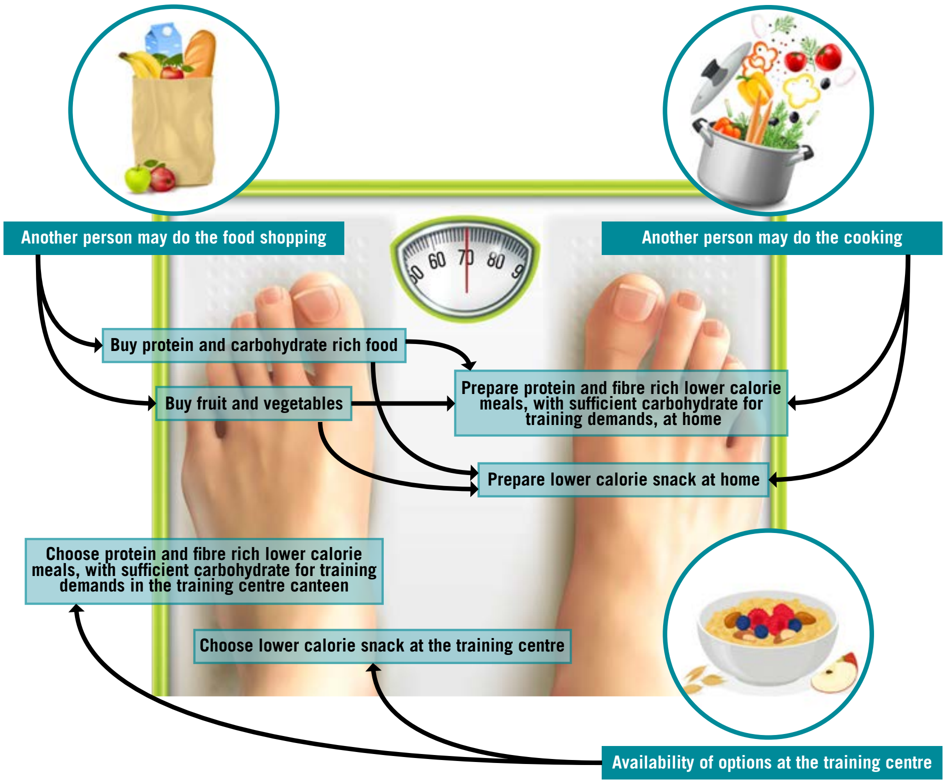

Figure 1: Behaviour as part of a system: An example of weight loss nutrition behaviours*.

**Please note this is note an exhaustive example, for instance meal and snack planning may be considered another behaviour and may be required prior to doing the food shopping.*

mass uptake of novel technologies brings with its new opportunities for practitioners as we enter an era of hybrid coaching[13].

The aim of this article is to provide a contemporary review of the theory and evidence-based tools developed in behavioural science, detailing how best to use these tools to provide sports nutrition support and explore how these strategies can be combined with advancements in technology to anticipate the future of sports nutrition. Although there are multiple health behaviour change theories, this article will focus on the use of a classification system known as the behaviour change wheel (BCW) and its supporting tools[8-10]. The BCW itself was synthesised from a total of 19 frameworks of behaviour change. At its centre is a 'behaviour system' broad enough to be applied to any behaviour, surrounded by a ring of nine intervention functions and an outer layer of seven policy categories. The stepwise practical application of the BCW and its supporting tools has been adapted from the previous work of Professor Susan Michie and Dr Louise Atkins for the sports nutrition audience and is discussed below[14-15].

Designing for Behaviour Change

For clarity, a behaviour can be defined as anything a person does in response to internal or external events. Actions may be overt (motor or verbal) and directly measurable or, covert (activities not viewable but involving voluntary muscles) and indirectly measurable[16]. Ultimately, behaviours are physical events that occur in the body and are controlled by the brain.

An obvious and crucial first step in designing any behaviour change intervention is *selecting the target behaviour*. Despite sounding simple, this first hurdle is often where many fail, either by casting the net too wide, failing to specify a single behaviour or small number of bundled behaviours, or in wrong direction, and express the target in terms of an outcome. For example, targeting 'decreasing energy intake' is too broad, whereas aiming to 'lose weight' is an outcome and does not indicate what behaviours someone needs to do. It is also important to note that behaviours do not occur in a vacuum, but instead across dynamic systems and changing contexts. In fact, some behaviours are dependent on other behaviours, which needs to be taken into consideration during the design process. As a result, when building for behaviour change, practitioners should clearly identify (i) who needs to perform the behaviour and (ii) what the target behaviour is.

In sports nutrition, it is likely that there may be a range of behaviours that are relevant to the problem the practitioner is trying to solve, as illustrated by Figure 1. When faced with this dilemma, practitioners should consider each behaviour in terms of the difference it will make to the overall health or performance related outcome, and to what extent it can be realistically changed in that individual or group. It is also worth noting that starting small, with one or two key or bundled behaviours (e.g. buying the foods required for snacks and preparing those snacks at home from the example), may be a more effective strategy in the long run. This slow and steady graded approach can build up an athlete's beliefs about their own capabilities, otherwise known as self-efficacy, which can be an important mediator of change. To illustrate using the same example, shopping for and preparing snacks may be easier to execute and less time consuming of the athlete, but can increase the athlete's confidence in themselves and lay the foundation for shopping for and preparing main meals. Once the behaviour, or bundled behaviours, are selected it is recommended that *practitioners specify the behaviour(s) by describing them in as much detail as possible*, for example who needs to do what, where, when and how, how often, in what context and in some instances, with whom. Precisely specified behaviours are not only easier to target, but also measure.

With clearly specified behaviour(s) identified, the next task is to *understand the behaviour(s)* and why they 'are what they are' and what needs to change. This can be done using two specific tools. The first of which is a 'behaviour system' know as the COM-B model, where the initials stand for capability, opportunity, motivation and behaviour. The COM-B model states that for a behaviour to occur an individual will require all three of these components. These components can interact to reduce or amplify the likelihood of the behaviour. Each component can be divided into two primary types. Capability is split into physical (i.e. having the motor skills required to cook) and psychological (i.e. having fundamental knowledge of what to eat and when) able to engage in and perform the behaviour. Opportunity relates to factors that lie outside an individual to make the behaviour possible and is divided into physical (i.e. having the necessary access to required food/equipment) and social (i.e. people in your environment promoting good nutrition). Finally, motivation, referring to brain processes that stimulate or direct behaviour, are segmented into automatic (i.e. controlling impulses to relapse) and reflective (i.e. goals and intentional thought out decision making) processes. This COM-B model is generally the starting point for intervention design as the practitioner attempts to diagnose what needs to shift in the athlete in order for the behaviour to occur.

If a more detailed understanding of the target behaviour is required, the components of the behaviour system can be further elaborated to the Theoretical Domains Framework (TDF). The TDF is a framework that helps identify barriers and enablers of behaviour and is comprised of fourteen domains. This expansion can facilitate a more robust understanding of the target behaviour and also act as a practical tool to help guide a practitioner's choices. The COM-B and its causal links, along with its components mapped to TDF domains can be seen in Figure 2.

Following a behavioural diagnosis using the COM-B and TDF, Atkins and Michie[14-15] recommend *identifying intervention functions* from the nine suggested in the BCW. These intervention functions are broad categories of means by which an intervention can change a behaviour and include education, persuasion, incentivisation, coercion, training, restriction, environmental restructuring, modelling, and enablement. Atkins and Michie have identified a matrix of links (denoted by the shaded cells) between the COM-B model and the BCW intervention functions (see Table 1) which are likely to be effective in bringing about change in the targeted behaviour. However, this is not an exhaustive list and further research is needed in nutrition to better understand these links and their effectiveness under a variety of circumstances and contexts.

At this stage of intervention design, appropriate behaviour change techniques (BCT's) can be identified from an extensive 93 item taxonomy[17]. These BCTs can be described as the 'active ingredients' of an intervention designed and offer a wide range of options to sports nutritionist to bring the intervention functions to life. An intervention function may be comprised of multiple behaviour change techniques. In addition to the literature, an online tool, the Theory and Techniques Tool provides information about BCT's and their mechanism of action (MoA) and may be a useful resource to help guide a practitioner's selection during this stage of development[18].

All of these theoretical and evidence based behavioural science tools are available to sports nutritionists who are tasked with changing the eating behaviours of athletes. However, selecting the appropriate mode to deliver the intervention is also crucial. It is here at this stage where a range of mobile technology driven opportunities are emerging and hold promise for those willing to embrace change in sports nutrition.

Advancing Personalised Nutrition with Technology

Mobile technology now affords sports nutritionists the opportunity to digitally deliver nutrition interventions to their athletes from any corner of the globe. However, the opportunities appearing to surface as a result of advancements in technology are far greater than just removing the limitations of location.

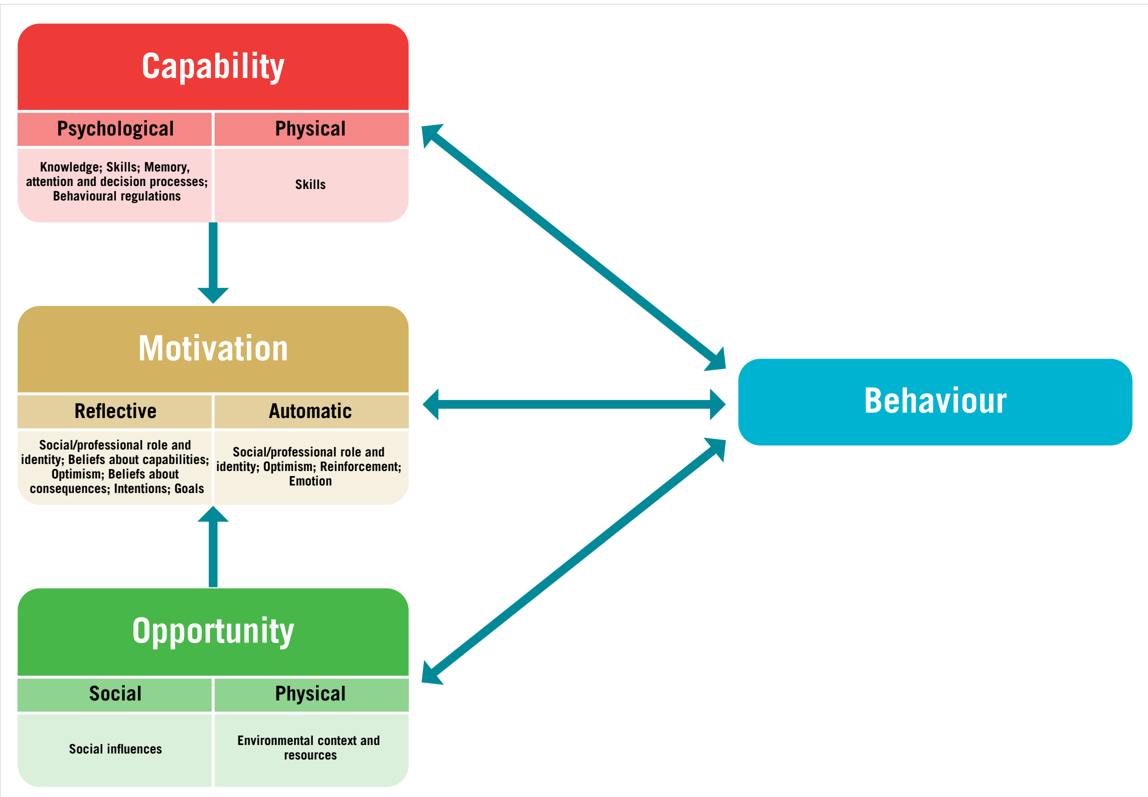

Figure 2: The COM-B model mapped to the TDF domains[14].

Table 1

COM-B components		Intervention functions: Education	Persuasion	Incentivisation	Coercion	Training	Restriction	Environmental restructuring	Modelling	Enablement
Capability	Psychological	■				■				■
	Physical					■				■
Opportunity	Social						■	■		■
	Physical					■	■	■		■
Motivation	Reflective	■	■	■	■					
	Automatic		■	■	■	■		■	■	■

Table 1: Matrix of links between COM-B model and BCW intervention functions[15].

Practitioners that choose to embrace mobile technology can now deliver continuous and scalable behavioural interventions, that can harvest vast amounts of data in real time and adapt to an individual throughout their behaviour change journey. These new methodologies and technologies over the next decade will enable practitioners to tailor interventions far beyond the current traditional "static" approaches that are now examined.

Moving from static to continuous tuning interventions

It is no secret that nutrition behaviours are complex, dynamic and individual. Naturally, the concept that tailored interventions are more likely to bring about change at an individual level is not new. However, most tailored interventions harness data from a single timepoint to determine how or what may be delivered. Furthermore, the decision to deliver intervention X, as opposed to Y, tends to rely on moderator analysis of previous interventions studies (i.e. literature determining whether the relationship between two variables is moderated by the value of a third variable). In short, generic interventions do not include specific individualisation components. Digitally delivered continuous tuning interventions on the other hand, support dynamic decision-making over time with adaptive algorithms generated based on insights at an individual level.

Sequential multiple assignment randomised trial (SMART) design is an example of a novel adaptive research design demonstrating increasing popularity in health-related studies such as weight management and also for other lifestyle related issues, e.g. smoking cessation[19-20]. It is a special type of randomised control trial, where it allows participants in the trial to be re-randomised multiple times during the trial, based on the individual's state at that time. For example, if the participant is responding well to the initial intervention given, SMART allows the participant to be re-randomised to receive a less intensive intervention. By randomising participants multiple times, scientists can assess the effectiveness of each stage and determine the optimal 'treatment' strategy and intensity.

Continuous tuning interventions take adaptive tailoring to another level. This novel class of interventions include real-time optimisation algorithms, which can further modify intervention content or aspects of its delivery to the needs of a specific individual, using methods such as reinforcement learning, control systems engineering, and N-of-1 study designs [21]. Decision rules can be used to link the tailoring variables to the available intervention options. These decisions can be triggered and executed automatically using a variety of computational methods, including analytics and artificial intelligence (AI). Continuous tuning interventions include, but are not limited to, just-in-time-adaptive interventions (JITAIs) and aim to provide the right intensity of support to individuals at the right time. JITAIs identify the 'right' moment to intervene by using enabling technologies, such as mobile phones, that capture the changing states of an individual. For example, an individual's state of availability or openness to receive support at a given time point may be dependent on their current activity, upcoming schedule or mental state. It is worth noting that age, treatment length, and primary outcomes of interest are not significant moderators of JITAI effects, highlighting their potential to reach multiple populations with various behaviours of interest. With regards to health outcomes, JITAI approaches have demonstrated significant health outcomes compared to traditional treatments[22].

Data for both adaptive and continuous tuning interventions may be collected using a method known as 'digital phenotyping'. Digital phenotyping involves the use of sensors and digital traces to infer psychological and behaviour constructs[23]. Figure 3 provides an example of a digital phenotyping model adapted from the Black Dog Institute/Deakin model[24].

The collection of this real-time data from smartphone sensors and other internet connected devices in a passive manner provides opportunities for the previously discussed behaviour change interventions to be delivered digitally and be made context aware. Context aware digital behaviour change interventions have the potential to improve health and performance related behaviours in athletes,

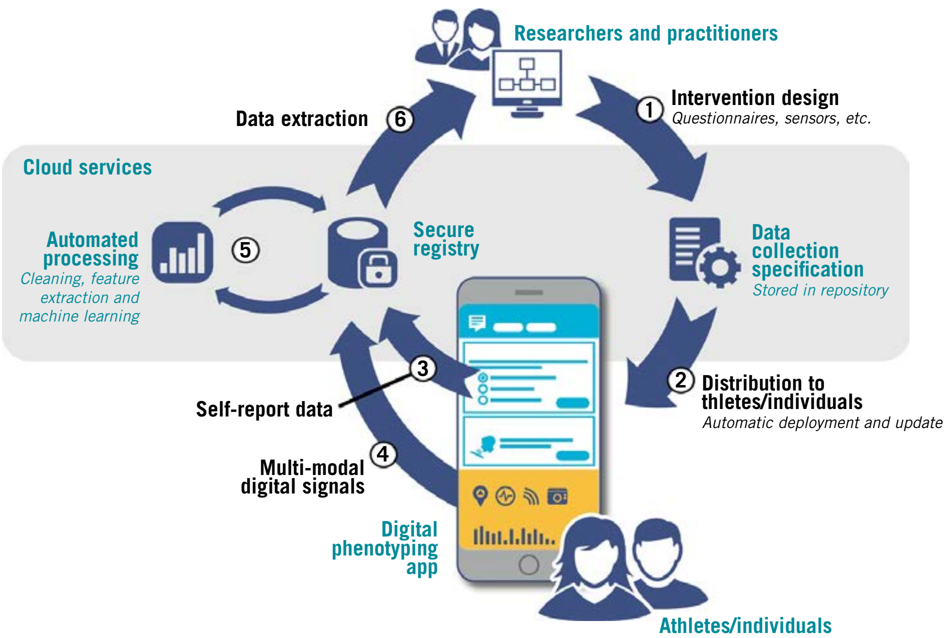

Figure 3: Adapted Black Dog Institute/Deakin model for a scalable, integrated multi-user platform for digital phenotyping research[24].

but ultimately more research is needed to really assess the impact of such approaches on nutrition behaviours. Additionally, the collection of this real time longitudinal mobile data may help expand our current understanding of theory and lead to the creation of new dynamic feedback theories of health behaviour[25].

The rise of intelligent systems and hybrid coaching

In addition to adaptive and dynamic tailoring, advances in artificial intelligence (AI) mean tasks that normally require practitioner know how can be algorithmically automated. In fact, AI itself refers to the ability of a computer or machine to mimic the capabilities of the human mind - learning from examples and experience, recognising, understanding, making a decision and responding. This global explosion of AI is remaking the world and disrupting many industries along the way, and even though AI is not yet permeating sports nutrition it does simply appear to be only a matter of time. Some practitioners may greet the technology with fear, presumably stemming from the concern around the perceived impact of AI on their jobs. However, economists say that jobs are likely to adapt rather than be lost during this period of change. Consequently, practitioners risk becoming "laggards" and falling behind the early adopters' as they progress into a new era of hybrid nutrition support.

Hybrid, in this instance, is referring to a combination of both humans and computers being used in conjunction with one another to deliver support. This novel approach may help build and optimise a scalable and continuous nutrition service provision system. This may be achieved by using computers for what they are good at, i.e. automation of algorithmic based nutrition tasks, so that practitioners can have more time to do what they're good at, i.e. coaching, developing relationships and having meaningful conversations with athletes. This hybrid approach is gaining traction in other areas of health such as smoking cessation and weight loss[26-27] and requires further exploration in the field of sports nutrition.

Fortunately, there has been an emergence of a novel technology in sports nutrition that facilitates hybrid coaching, delivery of adaptive digital behaviour change interventions and automation of algorithmic based nutrition tasks, e.g. menu planning, recipe generation and content delivery, the *Hexis Performance app* (see Figure 4).

This technology is now being piloted in large scale research trials, by a collaborative research team of individuals from Liverpool John Moores, University College London and Duke-NUS, combining skill sets from sports nutrition, exercise physiology, computer science, and behavioural science. Advancements such as the above highlight the importance of interdisciplinary collaboration between experts in various fields of practice to develop practical solutions that can be used by athletes and practitioners.

New methodologies and technologies over the next decade will enable practitioners to tailor interventions far beyond the current traditional "static" approaches.

CONCLUSION

Significant progress has been made in recent years in increasing our understanding of how to fuel the body to optimise training adaptations, reduce

Figure 4: The Hexis Performance app.

injury and illness risks, and enhance competition performance. However, sports nutrition is now transitioning into a technology driven hybrid coaching era where academics and practitioners need to collaborate with other fields of expertise to design interventions not only for the muscle, but also the mind. This implementation of theory and evidenced based behavioural interventions, combined with advancements in intervention design and technology, appear to now be the future of personalised nutrition. The author hopes this article will facilitate more interdisciplinary discussions, projects and publications engaging performance nutritionists, behavioural scientists and computer scientists, as this cohesive approach will be the driving force for modern and more successful approaches to sports nutrition.

CONFLICT OF INTEREST

The Hexis Performance app was developed by Applied Behaviour Systems Ltd. Mr Dunne, Ms Yan and Dr Impey, are co-founders of the company. Dr Cunniffe is also an advisor to Applied Behaviour Systems Ltd. The rest of the authors have no conflicts of interest in the authorship or publication of this article.

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