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A retrospective analysis of trick progression in elite Freeskiing and Snowboarding

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Abstract

This study offered a first examination of skill development within freeskiing and snowboarding, using semi-structured interviews to examine trick progression. Participants were purposefully recruited as performing at world top 8 level in 2014, the most recent Winter Olympic Games. A semi structured interview protocol, using a personalized progress chart, enabled the examination of trick progression across disciplines, with at least one participant from each of the events represented at the Games.Trick progression was achieved intermittently, moving through different stages during the year subject to experiencing the right conditions, training facilities, balancing time for progression with time for consolidation, competition periods and rehabilitating from injuries. There was high variance in the duration of trick progression between individuals and also high variance in the number of repetitions required in order to land a trick in competition. Imagery was a mental skill widely used and universally supported by our sample. Athletes and coaches should take directionality into consideration when planning their progression, ensuring all four directions are included and that pre-requisite manoeuvres are included in an athlete's training repertoire at the right stage in order to facilitate the learning of more complex manoeuvres at a later stage of development. Our data found a 60-40 balance between time-spent training on and off-snow, further research is required to determine the best combination of traditional strength and conditioning versus movement conditioning approaches, both from an injury prevention and a performance enhancement perspective.

Keywords: training modalities, directionality, skill acquisition, Olympic, quadrennial,

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In an earlier paper, we highlighted the tensions inherent in the new Olympic disciplines of slopestyle and half-pipe freeskiing and snowboarding (Willmott & Collins, 2015). Specifically, the training challenge–athlete health balance was considered: a usual issue for most sports but a particular one for these high-risk disciplines. In this regard, Kotler (2014, p. vii) emphasizes the recent "unprecedented flowering of human potential" that has occurred over the past three decades in the action and adventure sport domain, and cites the recent and profound progression of competitive freeskiers and snowboarders amongst big-wave surfers, mountaineers, free divers and whitewater kayakers as extreme examples of the pursuit of ultimate human performance. The comparative youth of the sports themselves, plus the recent changes to commitment and training patterns generated by the move from lifestyle/adventure activity to Olympic sport status, have added to the need for insight into skill progression. Specifically, a comparative dearth of investigation, together with this recent but powerful change, has effectively negated what little data were already available (e.g. Collins, Collins & Willmott, 2016). Such information is essential to the coach for effective planning, monitoring, and direction of athlete progression (cf. Plisk & Stone, 2003), and so this lack is a significant issue. For example, and as just a few of many considerations, what are the levels of psycho-emotional loading which characterize elite athletes' development in this high-risk environment? How might differences in the developmental template across individuals inform and enhance practice? Accordingly, in order to inform coaches on the safe but optimum progression of athletes in these sports, a current and detailed picture is required.

Providing further complication, evolution in the sport has resulted in an increased variety of training approaches and modalities, combined in a number of permutations and schedules. As a result, athletes and coaches have tended to either follow the anecdotal/biographical

accounts of established elite athletes, or to be overly influenced by the waves of new but unspecific sport science support now available to move towards an apparently well-structured but, so far, evidence-light schedule. Once again, the need for clear and concise data is clear.

Finally, and from a more theoretical perspective, the range of challenge inherent to the sport offers opportunity to examine the style of technical development across elements, thus supporting the picture in similar sports. For example, do athletes and coaches push ahead with technical difficulty in one direction or axis only, building on their inherent strengths and preferences at the expense of others? Or, in contrast, and especially based on a recent focus on variety in the judging criteria, is a more holistic (left and right, upright, corked and flipped rotations, forwards and backwards approaches) developmental pathway more effective?

Based on these important but unanswered questions, the first objective of this exploratory and descriptive study was to gain a retrospective and in-depth understanding of trick progression (technical skill acquisition and refinement) of elite freeski and snowboard athletes over the last Olympic quadrennial. We were particularly interested in the time course and number of repetitions during a tricks' development from initiation through practice trials to incorporation in high-level competition, and the pace of overall development (including fast and slow periods). The level of perceived challenge experienced when training through the various stages was a key and integral consideration. Additionally, we were interested in identifying factors that promoted progression: training aids, cognitive skills used and elements such as specific versus general transfer (for example developing a new trick based on pre-requisite manoeuvres versus general movement ability required to progress). Directionality (the variety of directions and axes that tricks can be performed in) was a further focus area, along with an investigation into the level of planning for progression, and the impact of the Olympics on planning and embedding a competition run (Carson & Collins, 2016).

In a new and rapidly changing sport, with limited attention in the literature to date, we identified a useful and important opportunity to inform a clear picture of an elite athlete's daily training environment. Given an understanding of the 'what' of trick progression in objective 1, the second objective was to increase understanding of the 'how' of trick progression. Determining the relative weighting (in terms of time and effort) which athletes placed on different training modalities, including on and off snow components provides information on the current balance of training, which in turn underpins coaches decision making in order to optimize their athlete's progression. Across both objectives, we aimed to provide practical implications and considerations for athletes, coaches, support staff, and high-performance programmes to help achieve their goals of athletic, major event, and Olympic success.

Method

Participants

Eight elite athletes (M_{age} = 22.5 years, SD = 3.42) from New Zealand and the United Kingdom along with their respective national coaches, (N=5; M_{age} = 38.8 years, SD = 10.83) were purposively selected into a stratified sample, with at least both one male and one female athlete engaged in each of the three new Olympic disciplines: freeski halfpipe, freeski slopestyle, and snowboard slopestyle. All athletes represented their country at the Sochi 2014 Winter Olympics, where six achieved top-10 results, the two remaining athletes were injured at Sochi, but have since achieved major event podium results. To maintain participant confidentiality, athletes' demographics are kept deliberately brief (Table 1). Athletes were recruited by contacting their coaches and National Sport Organisations (NSOs) and requesting their involvement in the study. Coaches were invited to assist their athletes in recalling their progression over the past four years, and to improve trustworthiness in the data (see below). Ethical approval was granted by the University's Ethics Committee, and

informed consent was achieved by athletes signing a form detailing the purpose, voluntary and anonymous nature of the study.

Interview Design

A semi-structured interview lasting approximately 90 minutes was completed (Appendix 1), recorded, and transcribed verbatim. Questions were developed through consultation between the authors, against the need to elicit participants' experience of trick progression. Pilot testing was completed with an independent athlete-coach dyad, leading to four slight modifications in the wording of questions. Each question was open-ended, thus yielding a variety of responses pertinent to each athlete and resulting in 22 single spaced, size 11 font typed pages of transcripts. Probes and prompts were used for clarification and elaboration of key points, and to obtain consistency in the depth of responses (Patton, 2002). Furthermore, in order to aid recall, and detail with respect to objective 1; athletes' were asked to provide a timeline sketch of their own progress against key tricks over the course of the past quadrennial (see Figure 1 for an example). This approach has been previously shown to increase the accuracy and veracity of recall (e.g., Drasch & Matthes, 2013; Ollis, MacPherson, & Collins, 2006). Finally, to specifically address objective 2, athletes and coaches were asked to weight training modalities and level of effort by completing an excel spreadsheet calculating % of time spent performing each modality, and identifying effort invested on a scale of 0 (zero effort) to 10 (maximal effort) to establish averages and variance across this sample (see Table 2).

Data Analysis and Data Trustworthiness

Content analysis of the interview transcripts was completed as a categorial breakdown: grouping responses that matched themes of the various elements of investigation. Trustworthiness was established through three means. Firstly, the involvement of the athlete and his/her coach increased reliability as athletes and coaches could confer or correct each

other to aid in recall of the details of progression over the previous 4 years. In all bar one of the interviews (coach unavailable), athlete and coach were interviewed together. Secondly, member checking was conducted whereby full transcripts plus selected quotes for each athlete were dispatched to athlete and respective coach, and approved. This resulted in no modifications or requests for change. Thirdly, a copy of the draft paper was approved by all participants (athletes and coaches), both with respect to the accuracy of the quotations used and also the veracity of the interpretations made.

Results & Discussion

To explore the elements of Objective 1 in greater detail, and to discuss and assess the impact of Objective 2, we now present our results and discussion, referring to the work of others where appropriate. We attempt to make meaning of our findings in a quest to gain a greater understanding of the complex nature of trick progression. Practical implications based on our findings are embedded within the commentary, with a concluding summary of implications for practice.

Objective 1 – Understanding Trick Progression

A halfpipe or slopestyle run involves the performer completing a series of discrete tricks. The judging criteria, measuring the quality of the performance of the series includes the following components: progression, amplitude, variety, execution, and difficulty (Association of Freeskiing Professionals, 2015). Thirty-three competitive tricks (halfpipe or slopestyle jumps) landed either at the Sochi 2014 Winter Olympics or at other major events that year, were tracked through use of the timeline approach. To ensure uniformity across all participants, rail tricks (which only feature in slopestyle, not half pipe) were deliberately excluded.

Of the 33 tricks, 14 (42.4%) were learned prior to 2010 and maintained or refined in the quadrennial leading into Sochi 2014, while 19 (57.6%) were developed within the

quadrennial. Of these latter 19 tricks, nine were learned using an airbag (all nine by halfpipe athletes), seven on snow in training, and three were landed for the first time in competition. Thirteen of the 33 tricks were considered upright spins (where the head remains above the centre of mass throughout the rotation), seven involved a single cork/flip (where the head dips under the centre of mass during the rotation), 10 involved a double cork/flip, and three involved a triple cork/flip.

Of the nine tricks developed using an airbag, the total amount of time between first trials on an airbag and first landing the trick on snow averaged 13.4 months (*SD* = 4.9). Of all the tricks learned within the 2014 quadrennial, the total amount of time between first landing the trick on snow and first landing the trick in competition averaged 7.4 months (*SD* = 9.1).

The developmental pathway for each trick was of particular interest. P4 identified the pathway for trick development from initially thinking about it, to general off-snow training, to more specific on-snow training, to trials on snow:

> Start with thought process and visualization and then move into airbags and other forms of trying the trick without having the full risk of hurting yourself (including trampolines and that sort of stuff) and once you have it on the airbag and have done it a bunch of times and landed onto your feet 3 or 4 times in a row then it's ready to go to snow.

With regard to supporting training modalities, athletes indicated using training methods including trampoline for general aerial awareness and air bags (providing a cushioned landing) for specific preparation. Notably, however, the two modalities were carefully and explicitly differentiated:

> When I trampoline I try my best to not think about skiing and just enjoy the trampoline – because it is the spatial awareness that I am getting from it – it is too close and too far away from skiing. When I was a grommet [beginner] learning corked 7s yes I would learn them on the tramp, but now I try and make that separation really clear in my mind

> – there's not a trick I can learn on the tramp which means I am closer to doing it on snow, it is just the spatial awareness. (P2)

This differentiation was reflected in all participant responses and is also apparent within the 'received wisdom' of the sport. For example, Shaun White (double Olympic champion in 2006 and 2010) pioneered the use of the on-snow foam pit in 2008 at his private training facility in Silverton, Colorado in preparation for the 2010 Winter Olympics. Subsequent innovation to address the challenges of building foam-pits in the alpine environment led to the proliferation of the use of air-bags at training camps: a similar type of apparatus that can achieve the same training effect as the foam-pit and is more practical to set up. These facilities provide a highly specific lower-risk environment where mistakes can be made, kinaesthetic awareness can be developed, and successful movement patterns can be honed prior to attempting the skill on snow:

> Sometimes if it's available and if it's going to help I use an airbag and then do it [on snow]. Most of my tricks I have learned I haven't used an airbag to learn them, it's only the last few that I have and that's because it has been available and easy. All my pipe doubles I've learned on a bag. (P1)

Reflecting this differentiation, however, athletes made varied use of training aids in the development of new tricks. As P5 stated "Trampolines, foam pits, airbags, it just depends what kind of trick it is, we normally start working on tricks in the summer and then you can learn it on soft snow".

As a further, but perhaps more naturally occurring aid, some athletes, particularly slopestyle, found that soft snow conditions at summer training camps and in the spring time were more conducive to landing tricks for the first time, although one halfpipe athlete noted the consistency in shape of features and speed in winter snow being advantageous to high-end skill development:

> I find that soft snow helps mentally more than anything, although in the halfpipe I would rather an icy pipe to try a trick in purely because it's not going to move on you; you pop and it is still there you can feel everything rather than in a soft pipe where it deteriorates throughout the day and you have a small window of opportunity and you might miss it by 5 minutes and you push into the snow and it gives way on you. A lot of people only like to try things in spring – on jumps it is way more mellow, icy jumps are scary, and icy pipes are scary but I like the whole staying the same, the consistency of the snow. (P4).

Pace of development, number of repetitions, level of challenge. When a trick had been landed on snow, the next stage was to consolidate that trick – make it more robust and then prepare to land it in competition. Some participants remarked that a new trick could be transferred from training to competition after just a few repetitions:

> I would chuck it in comp pretty much as soon as I've landed it in training – as long as it's clean enough, I usually get tricks pretty quickly if I can grab it [holding the board/skis to demonstrate control and earn higher marks] then I will do it in a comp…I always make sure I try a trick 3 times to make sure it wasn't just a fluke, but generally if I've got a trick that I have put a grab with straight away then I would class that as competition ready. (P4)

P3 agreed "If you landed it the first 3 times you tried it in training, that's a pretty solid land ratio, so there's no reason why you couldn't use that". Others required slightly more repetition: As P7 observed "I feel that I have to land a trick consistently until I feel confident at least 10 times before putting it in a comp run."

Notably, however, some athletes took significantly longer to take certain tricks into competition:

> For the dub 12 it took ages – like 2 years – I did it at spring camp 2 years before…but then for a left dub 9 it happened the season after. I probably learned 9's in a comp, or the cab 10 at the Olympics I had done a couple at spring camp 2 or 3 years before, then I just decided to do it and did it perfect in training and then did it in the comp. (P1)

In fact, there was evidence for considerable variation (from a number of days to a number of months or even years) in the duration of trick development, both within and between participants:

> You can do two of that trick that you have been petrified of, and suddenly it's like I know I can do that trick next season and I have got it dialled. It can be really short…like 3 days of doing it – solid days – you might need 3 months to get those days, but 3 days' worth of doing it can be enough. I know it seems pretty daft and pretty short but it can take you all season to get that. (P2)

There was also evidence for an impact of mood-state on skill acquisition. When asked about the difference between harder training tricks versus tricks landed in competition one athlete answered:

> I think it's because so many aspects need to be right on the day for you to be able to do tricks like that. The jump for the [trick name] was made for it pretty much, the conditions were perfect and I was in my right frame of mind, with my friends and everything like that, and you need those things to be in place when you are learning and trying new tricks. (P3)

The bottom line from these different perspectives is that, at the present early stage of the sport's development, trick progression is extremely varied and idiosyncratic. To provide a summary so far, our research provides two key findings. Firstly, trick progression is usually achieved intermittently, moving through different stages during the year subject to experiencing the right conditions, training facilities, balancing time for progression with time

for consolidation, competition periods, and rehabilitating from injuries. Our second key finding related to results shows that there was high variance in the duration of trick progression between individuals and also high variance in the number of repetitions required in order to land a trick in competition.

Of the elements that *thwarted* the pace of development, pressure of the Olympics (more detail later) and injury were highlighted across our sample. It is clear that aspirant elite podium athletes need to increase the level of difficulty of the discrete skills within their run on an ongoing basis in order to improve their ranking within the sport. Moving faster than the progression of the sport, to get to and then remain at the cutting edge has an inherent high level of challenge however (see Kotler, 2014 for a commentary). This, in turn, has implications for the participant profiles of successful action sports athletes (e.g., high sensation seeking: Guszkowska & Boldak, 2010; risk-taking personality types: Castanier, Le Scanff, & Woodman, 2010) and the incidence and mitigation of injury risk (e.g. Wijdicks et al; 2014; Willmott & Collins, 2015) The epidemiology of injury in snow sports has received plenty of attention elsewhere;, therefore further discussion is more sensibly focussed on methods to minimize injury risk through development stages.

Six of the eight athletes highlighted that repetition and volume was a key aspect in reducing the level of challenge of a trick:

> It's not even the difficulty of the trick it's more how many times I have done it. To a lot of people a rodeo 9 is way easier than a forwards dub 9, but I would rather do a forward dub 9 before a rodeo 9 because I haven't done rodeo 9's forever, so the thing for me is the more I have done something the easier it is and that's no matter what it is. (P1)

> I start on something small, something that I can under-commit to, say it's a rail trick, something low without stairs, so I can under-commit and be fine and then build from

> the feel. Then I take it to something bigger, on a jump I start on something real small and I spend a lot of time in the building process, I've noticed compared to some other people – they will learn it on this jump and take it straight to another one, but I have noticed that I am usually more consistent than people that do that with their tricks. It's slow and steady. (P8)

The extent to which this repetition was necessary for emotional reasons (less nerves, greater confidence) rather than embedding the trick motoricly (cf. Carson & Collins, 2016) is an important issue which awaits further investigation.

Factors that promote progression. In most cases, the level of challenge and risk of injury was deliberately reduced when developing a new trick. Methods identified involved off-snow facilities including general training on trampolines, and more specific options such as ramps into foam-pits, and on-snow facilities including air-bag landings. New technologies are improving the quality of such training facilities. For example, "super-tramps" have evolved which allow an athlete to bounce higher with less impact on their bodies and require less specific skill to recreate snow sports manoeuvres. As another recent evolution, artificial dry slope jumps into sloping air bags have emerged that have advantages both in the ease and quantity of access (they can be built close to high-density population areas, and have potential to be accessible year-round) and their higher level of specificity to an actual jump. In short, the challenges of learning new tricks are getting lower although they are still significant.

Of course, access to high-quality training facilities within a feedback-rich environment is essential to optimize the skill acquisition process, increasing the level of feedback in the environment, including activation of all senses, is perhaps an area which deserves further consideration. Transferring manoeuvres from artificial apparatus to on-snow training

environments and competition relies on a successful transfer and maintenance process, and represents the enduring challenge inherent within the sport.

Notably, cognitive skills were commonly reported as key to overcoming this challenge. The use of imagery, both visual and kinaesthetic, was identified by most athletes as a crucial and necessary part of skill acquisition; the first stage in developing a new trick, and then used throughout the process. P1 stated "I do heaps of thinking about it, visualization and imagery." P2 expressed similarly "I am quite psycho with my visualizing, I am really dialled, I will be in my room by myself and I can't lie flat, I will find my little space and I will visualize for ages." Imagery was widely used and universally supported by our sample, especially as a tandem approach with physical practice (cf. Toussaint & Blandin, 2010). Imagery was used within training sessions to aid skill acquisition, and also between the sporadic periods of facility access impacted by seasonal and financial constraints. Of course, imagery ability has also been shown to enhance confidence (Williams & Cummings, 2012), and this was seen as key to successful performance, particularly in this sport with its' high inherent injury risk.

Future use of imagery approaches for learning new skills would certainly merit further investigation, however. For example, the degree of functional equivalence of motor imagery to achieve complex motor actions that have not yet been performed has been questioned by Olsson and Nyberg, (2010), who suggest that you cannot effectively image a skill until you can perform it physically. To use a snow sports example, it is unclear whether there is enough neural overlap between a frontside double cork 1080 and a frontside triple cork 1440 for example, to allow an athlete who has already mastered the frontside double cork 1080 to assist acquisition by effectively imaging a frontside triple cork 1440. In simple terms, research which examines the "projective scope" of imagery is urgently needed. For the moment, however, it would appear that the closer an athlete can get to replicating a novel

manoeuver through effective imagery, the more neural overlap will exist. Certainly, our sample found that a combination of such *projective* imagery, often combined with observational learning based on watching others performing the trick (cf. Ram, Riggs, Skaling, Landers, & McCullach et al., 2007) was an extremely useful adjunct.

Watching others perform a skill in person or via media is a facet embedded in the culture of snow sports (Willmott & Collins, 2015). Progress from one corner of the globe is immediately transmitted via social media, and so the opportunity for modelling the latest breakthroughs is readily available. As per imagery, modelling enhances confidence (Hall et al., 2009), and its effective use both in-training and intra-training sessions was reported by our sample. Modelling assists in the formation of cognitive representations (Ram et al, 2007) and, in our sample, it was the combination of modelling and imagery which yielded the best effect in terms of acquisition and retention (cf. Hall & Erffmeyer, 1983).

These advantages notwithstanding, physical practice was still seen by some of our sample as the real key to progression. In contrast, some athletes indicated that it was possible for a trick to be landed in training and then performed in competition after only a small number of repetitions; in fact, three of the 33 tricks tracked were landed for the first time in competition. The question of what discriminates between those athletes who can land tricks (and tricks that can be landed) from such short preparation is another question which awaits further investigation.

Extrapolating from both our data and our experience (as a national snowsports coach, and an experienced performance psychologist) however, we suggest that athletes with a greater movement vocabulary (access to a broader base of motor programmes) are able to integrate new tricks into competition swiftly as they have greater neural overlap between existing movement patterns and desired movement patterns. If a new trick was in a preferred spin direction for example (more on this later), and the athlete had a strong foundation of

prerequisite skills, a new trick may have been landed for the first time within a short time frame. Adding 180 degrees of rotation to a previously mastered trick, for example taking a left triple-cork 1440 to a left triple-cork 1620 was achieved for the first time in a competition run by P3, 11 months after the 1440 variation had first been landed. Data suggested that the 11 month period of mastery was necessary in order for the athlete to focus on execution and attain the control required to add the additional 180 degrees. Further longitudinal research is required to gain a better understanding of exactly *how many* repetitions it takes (in this example within the 11 month period) in order to move a trick along the continuum from first landed to mastered. For the moment, our paper offers a basis for practitioners to apply.

Of course, learning a skill is only part of the battle. While increasing progression and technical difficulty is a fundamental focus of action sports athletes, it is the execution element of the judging criteria which is a skill in itself and will ultimately separate those on the podium performing similar levels of difficulty. There is a desire from many athletes, and an ethos in the sport which is mirrored by judges, to ensure that style is not lost and the aesthetics of performance are accentuated (Thorpe, 2009). To separate from the rest of the field and to avoid robotic movements, a focus on individual subtle variations and style or execution factors is recommended. Other action sports (e.g., surfing; Wilson, 2012) are also caught up in the competing perspectives of technical progression at the expense of style, and it is clear that a keen focus on maximizing both elements will reap the greatest reward. Thus, research in support of performance in these sports must also allow for the aesthetics inherent in subjectively judged events, in parallel to the processes of skill acquisition.

Directionality. Freeskiers perform in a symmetrical stance and generally report a spin direction preference – spinning to the left or to the right is considered their "natural" direction while spinning in the opposite direction is classed "unnatural". Snowboarders have different biomechanics involved in left or right spins depending on their stance (left foot forward =

"regular", right foot forward = "goofy"). Both freeskiers and snowboarders complete tricks forwards and backwards (='switch') in each direction, meaning four possible spin directions.

Asked to rate their level of performance on a 1–10 scale on the four spin variations, all our participants purported a spin direction preference, and reported at least 1 out of the 4 directions being notably weaker than the others. Participants' perceptions on their balance of spin and direction capabilities were of particular interest in order to understand the meaning of these data. As P4 observed "some spin better left or right, and I think it all comes down to time doing it." While others reported:

> I learned heaps of stuff to the left first and then I had to go back and learn it all to the right, the thing that made spinning right harder was that it was all new and felt harder – especially learning how to spin switch right side, looking over that shoulder was really weird and annoying and odd, the more I did it the more it became mellow. Still now, skiing switch right is like kind of weird. I can do my tricks that way, but bombing down the hill looking over that shoulder still feels real weird to me. (P1)
>
> Left side tricks, my unnatural way, are definitely the harder ones…with switch it's not in the air, but it's take-off and looking over the other shoulder which makes them hard… it's like trying to write with the other hand. (P5)

Variety in spin direction is a key part of the judging criteria (FIS Snowboard Judges Manual, 2015/2016). The gold medal X-Games winning run in men's freeski halfpipe has included tricks in all four directions since 2014, and jumps in all four directions in men's freeski slopestyle since 2013. The 2015 gold medal X-Games winning runs in both men's and women's snowboard halfpipe featured tricks in all four directions. Is it a concern therefore that the elite athletes in our study all report a deficit in at least one direction? Furthermore, is such a concern grounded in the pragmatics of performance or the potential contribution to elite levels of physical literacy?

Many slopestyle courses, including the Sochi 2014 Winter Olympics only have three rail sections and three jump features. In these circumstances, a slopestyle athlete is not disadvantaged score-wise if one of their spin directions is considerably weaker since they can simply leave it out of their run, or complete the fourth direction within the rail features. Furthermore, the Pyeong Chang 2018 Winter Olympic slopestyle course will also have three rail sections and only three rather than four jumps (Chae, personal communication 23rd August, 2015).

In fact, the advantage may be more implicit to total development than explicit to the competitive challenge, however. For example, Heinen, Vinken, and Velentzas (2010) point out that, as the vestibular system is placed upside down when a gymnast is inverted, there is an inevitable misperception of turning direction. With the complexity of single, double, triple, and now quad cork manoeuvres, where the head may pass beneath the centre of mass multiple times, an elite freeski or snowboard athlete, just like an elite gymnast, needs a well-tuned vestibular system that is comfortable spinning in all directions and in multiple axes. In the same way that gymnasts must master fundamental moves in specific directions in order to be able to perform more complex moves (Heinen et al., 2010); freeski and snowboard athletes benefit future progression (and scoring potential) by developing fundamental skills in all four directions.

Also of interest and with previous attention in gymnastics, (Heinen et al., 2010) was the transfer of learning from one spin direction to the other. For example, P6 indicated that it took 16 months from first attempting a right double-cork trick variety into the airbag to landing it in competition, while 4 months later, the same double-cork trick to the left took just 3 months to transition into competition. This clearly reflects the impact of lateral transfer shown in other motoric challenges (cf. Collins, Morriss & Trower, 1999). Furthermore, it has been demonstrated elsewhere (Smith, 2001) that learning a manoeuvre in both directions in

the same session can increase both acquisition and retention. Athlete's working on a left 540 for example may benefit from acquiring both tacit and declarative knowledge while learning a right 540, that helps them acquire the former trick.

The strong correlation between ability in the four directions with energy invested in that direction amongst athletes in this study, along with reports that an "unnatural" spin direction can feel more "natural" after significant repetition, suggests it is the responsibility of the athlete and/or coach and/or performance planner to ensure that energy is invested appropriately in order to achieve the required balance across the four spin directions.

Level of planning for progression. Given the relative youth of the disciplines as formal sports, and the free spiritedness of their origins (cf. Willmott & Collins, 2015; Ojala & Thorpe, 2015) it is perhaps unsurprising that athlete planning was somewhat hap-hazard. That said, and also unsurprisingly, the planning approach varied between athletes. For example, P7 identified careful goal selection with their coach:

> I think we followed the Individual Performance Plan pretty good – we set out goals for every training period and we try to achieve those goals and keep chipping away at it. I have an overall goal and what I want my run to look like for 2018, but we work more specifically in 6 month chunks.

In contrast, another athlete identified the added pressure of externalizing goals and preferred to progress in keeping with the established social milieu by one-upping each other on a spontaneous basis:

> There might have been plans on paper, but my progression was always out of the blue, like 'it's time to do this', like my switch triple this year at X-games, I've planned to learn a triple, but then it was like the day before it I knew that it was the time to do it…some tricks work sometimes and sometimes they don't. (P1)

While development of a comprehensive and detailed planning habit may provide significant benefit for some athletes, trick progression is highly variable-dependent (i.e., weather, mood, facilities, etc.) so it would seem that some adaptability in planning is essential. Certainly, at least for the moment and in keeping with existing advice in other sports, catering for individuality in planning approach would also seem to be key.

Impact of the Olympics on planning and embedding a run. It was the first time at the Olympics for some of the sports and all of the athletes in the study. Most mentioned the fact that the Olympics provided a definitive timeframe by which trick progression needed to be completed. This was significantly different in nature to previously preparing tricks for competition because it was a quadrennial rather than an annual cycle (e.g., X-Games). As P4 observed "You have one shot and you need to be at the forefront of it…It seemed to put a ticking time bomb on it all"; a view supported by another participant:

> It did give a deadline, for the first time. You are always learning tricks to put them into the next contest, be it one of the 10 contests that you do in a season. But the Olympics wasn't like that, it was boom here's the date and you need your shit sorted by then which we have never had before… normally it doesn't matter because if it's not this contest it's the next. (P3)

In terms of preparing a run for the Olympics, P4 identified that planning was on a need-to basis, reacting to advancement of the field and breakthroughs by other competitors:

> Seeing people come out with stupid new tricks that you have to learn quickly – that was the hardest part, people doing new tricks closer and closer to the time [of the Olympics] and realizing you were going to need them and learn them quickly

The media hype and increased support and focus from NSOs was also credited with placing a special emphasis and brighter spotlight on the athletes than had previously been experienced.

In this regard, it seemed that the concept of peaking was facilitative to some while debilitating to others:

> If I wanted to keep winning comps then I had to do these tricks – I never had a pressure of having to do tricks, then all of a sudden I had the pressure of doing them so then they became massive in my head…rather than figuring out how to get there – they became unattainable in my head. (P1)

> First-time ever, suddenly the countries give a shit about you and they are breathing down your neck, it was more a pressure rather than a 'let's do this', it's like 'I have responsibility greater than my own career. (P2)

Special impact of the Olympics notwithstanding, participants also acknowledged the more general development in profile which had already impacted on the sport:

> It gets so much more intense now especially in the Olympic year in the build-up…and I don't think it's just the Olympics, the whole industry has grown and there's so many more kids that want in. There used to be about four or five of us that could win a comp at any comp and it was just like rotating and now there's about 20 that can win the comp and they are all just as hungry. (P1)

The pressure of the Olympics and attention from NSOs was novel for this group. Debilitative elements of Olympic pressure presented with the associated impact of NSOs involvement may have exerted a greater pressure due to this novelty, and we would expect that subsequent generations would be more aware of, and better prepared for, such challenges. Whether the sports inclusion was opposed or embraced, however, the impact of the Winter Olympics certainly provided a whole new level of challenge, which was viewed as being facilitative for performance levels, albeit sometimes only in retrospect!

Objective 2 – Relative weighting of different training modalities

Athletes were asked to estimate the percentage of time spent across different training modalities over the course of the past four years (see Table 2). As shown, on-snow training including fundamental skills, freeriding, trick progression, consolidation, and competition accounted for a cumulative total of 60% of their time while time-spent training off-snow accounted for 40% with minor variations between athletes (ratios ranged from 70:30 to 54:46). Off-snow work included off-snow movement (trampoline, gymnastics and moving platform sports), physicality and robustness, mental skills, training approach (planning and reflection), and recovery. The largest variation across logged activity was in the percentage of time athletes spent learning new tricks which ranged from 10%–40% of their time. Importantly, the high variations apparent across athletes' self-reported activity support our earlier statements on the significant individualities within the sport. As P8 summarized:

> Trampolines are a new thing for me that I am starting to learn. [On snow], it has been quite a progressive week and that was in really slushy conditions and again that is a new thing. Basically learning is starting on the smallest feature in parks; that's where I learn the most…ground stuff including learning how to move my hips over my board. I also use a lot of video analysis – it is massive for me, I don't do as much imagery as I could…I used it a lot when I did the [name of trick] and it helped a lot. And I also do meditation which helps calming down with some of the harder tricks – learning how to quieten the mind.

In short, athletes use a wide variety of methods in a wide variety of ways.

A similar picture was apparent in the data on self-reported energy invested across the various tasks (see Table 3). Athletes collectively invested the most energy in competing and learning new tricks and the least in recovery and training approach. Variations were also apparent across the key components of competition and trick progression, with seven out of eight athletes interviewed rating competition maximally, and six out of eight rating trick

progression at the same level. Within this variable picture, however, these athletes were clearly most committed to on-snow work. The average score for energy investiture across the on-snow training modalities was 7.88/10 while the average score across the off-snow training modalities was 5.8/10.

Our balance between on and off snow components in both time and energy invested represents a stark contrast to Turnbull, Keogh, and Kilding's suggestion (referring to elite snowboard halfpipe athletes) that "as a consequence of the sporting culture and self-expression ethos of board sports, the athletes commonly have little inclination to do off-snow training" (2011, p. 7). Does this demonstrate a shift in culture over the period of the last quadrennial? Is this shift unique to those athletes now involved in Olympic disciplines? Whatever the reason, long gone are the days where action sports athletes just got better by doing their sport (cf. Ojala & Thorpe, 2015): although, unsurprisingly competing and trick progression received the highest levels of energy investment and effort.

Of course, and as in other sports, getting the right balance of training is critical to achieving optimal progression in freeskiing and snowboarding, with off-snow training focussed towards enhancing the quality and quantity of on-snow training (Kipp, 1998). Physicality and robustness training ensures athletes have the strength, power, and endurance to be able to train to a sufficient level, and helps to protect them from inevitable impacts sustained while acquiring new skills. This injury prevention concept of off-snow training is clearly also applied through the off-snow movement skills described by participants, where an ability for cat-like fitness (always landing on your feet) was promoted. In parallel, performance enhancement was achieved through the development of specific movement patterns with a high volume of repetition easily achieved (i.e., trampolining). Importantly, however, further research is required to determine the best combination of traditional strength

and conditioning versus movement conditioning approaches, both from an injury prevention and a performance enhancement perspective.

Limitations and Future Directions. Our research provides an overview of performance improvement timelines, however it clearly does not measure when and how the "best" learning takes place: this can only be inferred. Furthermore, while we measured progression in terms of months from first trial to landing in competition, it is difficult to measure all of the general and specific training that took place within that period directed towards development and mastery of a trick. Clearly, further longitudinal research is required to achieve greater clarity in this regard. Methodological limitations of the current study also include the small sample size (n=8) and self-report nature of the study. Furthermore, only one form of data collection was used. A quantitative follow-up would be beneficial to investigate optimal strategies to maximize progression and identify the ideal coaching approach in this context. Further exploration of the potential for and limits to the rate of progression will also benefit the action-sports community and coaches in particular increasing their awareness of what is possible, achieving the right balance of risk vs reward, most importantly reducing injury and informing their practice.

Conclusions and Practical Implications

Prediction work suggests that the sports are continuing to progress: tricks will be landed in competition in 2022 that have not yet been witnessed. It is also clear that, currently, high end skill development is a piecemeal approach and is not high volume. Athletes move through different stages during the year subject to experiencing the right conditions and facilities, balancing time for progression with time for consolidation, competition periods, and rehabilitating from injuries. Optimal use of training aids to reduce the level of challenge and, therefore, injury-risk should be considered by coaches to help athletes progress swiftly and safely along the trick development pathway, taking into

consideration their appropriate deployment from both a specific and a general transfer perspective. Novel approaches and further innovation should provide dividends.

Our results showed high variance in the duration of trick progression between and within individuals and also high variance in the number of repetitions required in order to land a trick in competition. For elite athletes challenging for the podium, acquiring new tricks in the current quadrennial needs to be achieved bearing realistic timeframes in mind and in tandem with refining and finessing existing tricks. A carefully planned approach is recommended, allowing for periods of learning and trick progression followed by periods of consolidation and execution with simultaneous maintenance of the existing repertoire.

Ways to speed up acquisition include manipulating the quantity and the quality of the currently limited training opportunities. Obtaining access to general and specific high-level training facilities for safe repetition will continue to be a challenge for the coach, but optimizing the organisation of practice is another important part of maximizing the effect. While imagery and modelling are currently widely used, we have identified the potential to further tap these powerful tools. Invoking a broader range of senses and including the rhythm and relative timing of the skill to aid in acquisition are suggestions to enhance this aspect. As discussed earlier, the speed of acquisition will also be impacted by the development profile and history of the athlete: those with a higher level of general movement ability and greater movement vocabulary may be pre-disposed to acquire new tricks faster.

Directionality emerged as a particularly fruitful area for immediate exploitation and future investigation. The athletes in this study suggested that the acquisition of skill in one particular direction was the result of time engaged in spinning in that direction, therefore for the committed athlete willing to invest time into their weakness the rewards are inevitable. If a spin direction is overlooked during developmental years, it was reported that significant energy was required in order to catch up at a later stage. In order for an athlete to avoid a

disparity in the strengths of their spin directions, and to benefit from the enhanced effects of lateral transfer, it is suggested that athletes spend equal amounts of time developing all four directions particularly during the formative stage of their career. Athletes and coaches should take directionality into consideration when planning their progression, ensuring all four directions are included and that prerequisite manoeuvres are included in an athlete's training repertoire at the right stage in order to facilitate the learning of more complex manoeuvres at a later stage of development.

Reflecting these varied considerations, it is clear that an individualized approach to off-snow training is required; taking into consideration an athlete's stage of physical development and maturation, carefully manipulating their off-snow training load to complement their on-snow load dependent on the phase of the season. With a potential increase in the repetition of more complex and physically demanding manoeuvres, athletes will inevitably be increasing their injury risk. There is therefore a need for enhanced physical conditioning to allow a higher number of repetitions to occur; likewise an increase in the quality of physical and mental recovery strategies.

Each of the athletes in this study were first time Olympians. Understandably the impact on their trick progression by this unique event was individual and varied. As the sport continues to evolve within the Olympic environment, success will be enhanced in those athletes that plan and prepare appropriately and embrace the positive elements of the Olympic spotlight while mitigating any negative elements. A key role in navigating these muddy waters, guiding an athlete safely to the top of the podium, is the coach.

It is crucial for ultimate performance, however, that in the quest for progression in terms of difficulty (more spins and more flips), the very essence of the sport: 'free', 'style', is not lost. Athletes must be encouraged by their coaches to continue to retain and progress their individual style and expression which will ultimately separate the good from the great.

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Table 1.

Participant Profiles

Label	Gender	Freeski/Snowboard	Discipline
P1	Male	FS	Halfpipe
P2	Male	FS	Slopestyle
P3	Male	SB	Slopestyle
P4	Male	FS	Halfpipe
P5	Female	FS	Slopestyle
P6	Male	FS	Halfpipe
P7	Female	FS	Halfpipe
P8	Female	SB	Slopestyle

Table 2.

Time spent working on different training elements

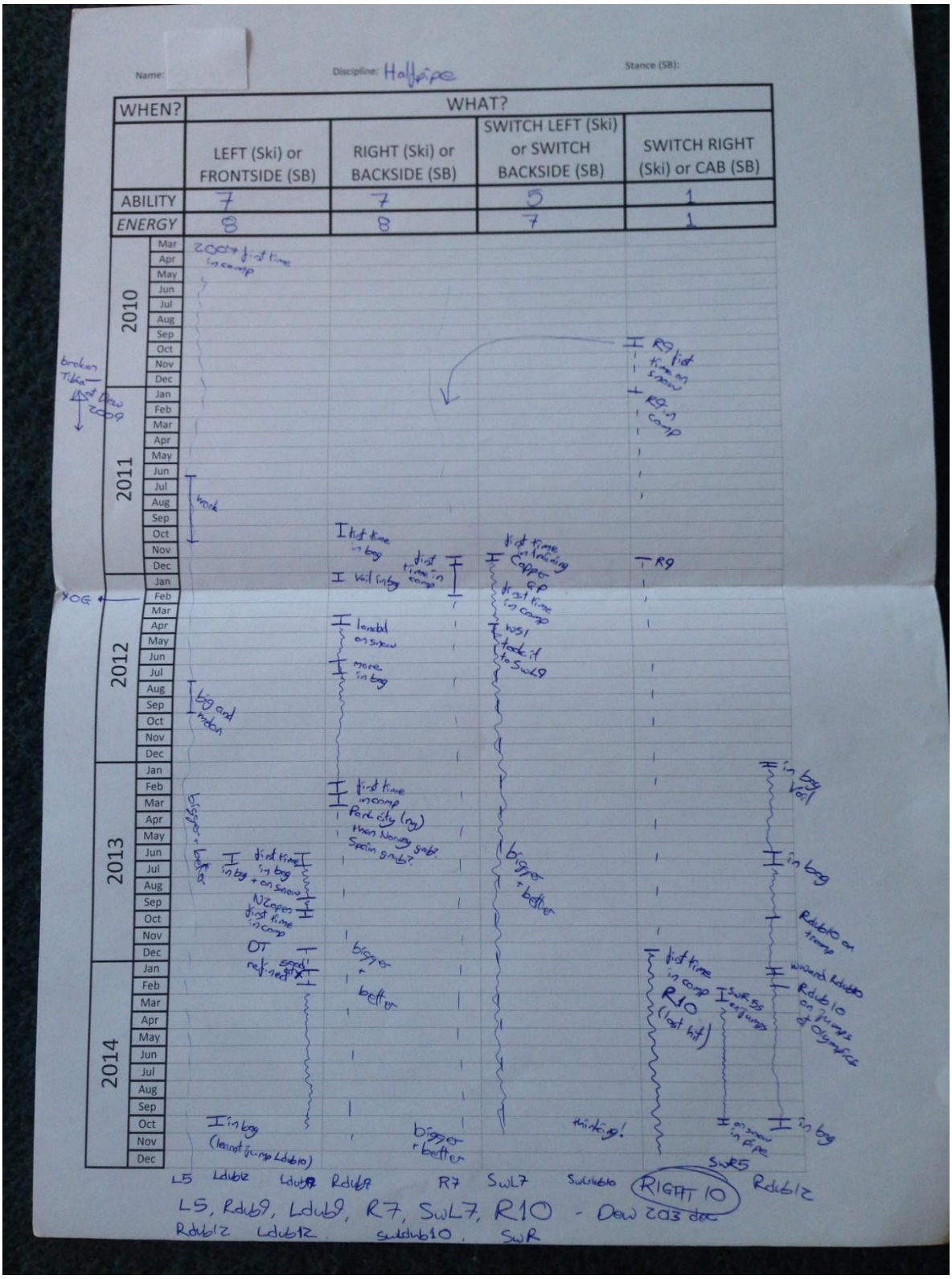
Training Modality	Mean % of Time Spent (SD)	Range
Off-snow movement skills (i.e., trampolining, skateboarding etc.)	6.25 (4.13)	1–12
Physicality and Robustness (i.e., gym work, prehab, conditioning etc.)	15.00 (7.87)	5–29
Mental Skills (i.e., imagery, self-talk, relaxation)	7.63 (5.76)	2–20
Training approach (i.e., planning & reflection)	5.00 (2.93)	1–10
Freeriding	8.88 (7.85)	1–20
On-snow movement skills (i.e., fundamental skiing/riding skills)	7.00 (4.24)	3–15
Technical skill development – Learning new tricks	16.88 (9.92)	10–40
Technical Skill Development – Amplitude, Execution, & Style	16.38 (6.41)	9–25
Tactical skills (competing)	10.63 (4.31)	5–15
Recovery	6.38 (4.41)	2–15

Table 3.

Summary of participant ratings for effort expended on different training modalities

Training Modality	Mean Effort out of 10 (SD)	Range
Off-snow movement skills (i.e., trampolining, skateboarding etc.)	6.29 (2.98)	2–10
Physicality and Robustness (i.e., gym work, prehab, conditioning etc.)	8.14 (2.04)	4–10
Mental Skills (i.e., imagery, self-talk, relaxation)	5.00 (1.83)	3–8
Training approach (i.e., planning & reflection)	4.29 (2.69)	2–8
Freeriding	6.29 (3.25)	1–10
On-snow movement skills (i.e., fundamental skiing/riding skills)	5.00 (2.58)	1–8
Technical skill development – Learning new tricks	9.57 (0.79)	8–10
Technical Skill Development – Amplitude, Execution, & Style	8.71 (1.38)	7–10
Tactical skills (competing)	9.57 (1.13)	7–10
Recovery	3.43 (2.23)	1–6

Figure 1: Exemplar Data Collection Sheet



Appendix 1. *Interview Guide.*

Question	Probes	Stimuli	Purpose
1. What is your current hardest trick? a) in competition b) in training	• What makes them the hardest?	• Overall difficulty • Gnarly-ness • Personal progression – I have found this sort of stuff difficult	• Establishes current performance level
	• What is the difference between the training and comp trick? • Why	• How long will it take to move the trick from single, training reps to a place in your comp routine? • What sorts of progressions/methods will you use?	• Starts to probe progression rates and methods
2. Considering single tricks, take me through your progression over the last four years?	• Where did you start?	• Think back to where you were performance-wise • Against major competitors?	• Looks at progression – both rate and line of advance • Planning process – is there one and who is involved? • Look for possible sticking points, lack of linearity, preferences for side/direction, etc.
	• Any waymarks or critical dates along the way (e.g., major comps, change in coach, etc.)?	• It MAY help to draw a timeline then work from that	
	• Was this done to a specified plan?	• How and when was the plan drawn up? • How far in advance do you look? • If no plan, who and how have progression decisions been made?	
3. How does this match the progression of your routine?	• When and why do you move a trick into your routine?	• How well does this work? • Has it ever gone wrong?	• As above

	• Is the evolution of routine based on how well/quickly you develop a new trick? • And again, is there a specific plan?	• What are the underpinning principles, if any, of how your routine progresses? • As above	
4. What are your favorite/usual/most effective methods for development?	• Bag/water jump • Trampoline/gymnastics work • Coach input and discussion • Training camps with others • Solo sessions • Imagery • Other (please specify)	• Relative weighting in frequency of use and importance • How these are combined together • Where/who did this come from?	• Varied use of training methods
5. How much is your progression impacted/influenced by that of your competitors?	• Watch them at comps • Watch them at camps • Listen to gossip/media • On my own path	• Social influences in the sport. • Has this changed over the last four years/as the Olympic push has come in?	• Solo versus group focused orientation