Designing digital tools for creative thinking: a case study from elite sports coaching

Everyday creativity support for sports coaches

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This case study reports the process, outcome and selected lessons from designing a new digital experience for professionals in one field that has received little interest in computer-human interaction research – elite sports coaching. The digital experience provided professional coaches with interactive support for thinking more creatively when overcoming the challenges faced by athletes and teams. It was one of the first to report the co-development of digital tools collaboratively with and for elite coaches. The case study argues that the digital outcome, called Sport Sparks, advanced the state of the practice in co-creative AI and digital creativity support by deploying the tool for use by professionals working outside of a recognized creative industry. The research team also learned lessons from its reflections about the process and outcome that can inform the development of co-creative AI tools both in elite sports coaching and other professional domains beyond the creative industries.

CCS CONCEPTS • Human-centered computing~Human computer interaction (HCI)

Additional Keywords and Phrases: digital creativity support, co-creative AI, generative AI, elite sports coaching

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1 INTRODUCTION

This case study reports the process, outcome and selected lessons arising from the co-development of a new type of digital experience for professionals in one field of interest – elite sports coaching. This digital experience provided professional coaches with interactive support for thinking more creatively when overcoming the challenges faced by athletes and teams. Although the case for creative thinking to improve elite athlete performance has been established (e.g., [26,36]), no digital support for it had been reported, even though digital tools on mobile devices can be more accessible to busy coaches than in-person training away from their immediate coaching environments. The co-development of the new digital experience with professional coaches gave rise to lessons of potential value to others co-developing digital tools to support creative thinking in both elite sports coaching and other sectors. It also extended the published creativity support tool research, most of which reports work undertaken in academic settings and/or with creative practitioners.

Creative thinking in elite sports coaching can take many different forms and produce a range of diverse outcomes. E.g., to deliver multiple marginal gains in performance in professional cycling, one team reported new ideas such as *riders traveling with their own mattresses and pillows*, and *using structured cool-down procedures after races* that impacted positively on cyclist performance [9] and emerged from directed creative thinking. According to established definitions of creative outcomes proposed by [24], these outcomes were pro-C, i.e., infrequent outcomes that exhibit professional-level expertise applied to earn a living.

By contrast, there are fewer reports of other forms of more frequent but lower-profile creative outcomes when solving sports coaching problems. These outcomes might include mini-C outcomes that are novel and meaningful interpretations of people's experiences [24], e.g., a coach learning a new technique for motivating a team from previous personal experiences. The outcomes might also include little-c outcomes [24] often novel to just one person, e.g., a training practice that is both new and valuable to an individual athlete. The research team hypothesized that more regular use of creative thinking techniques in elite sports coaching would result in more pro-C, mini-C and little-c outcomes, with subsequent positive effects both the coaching and performance of athletes and teams.

One possible reason for the lack of creative thinking in sports coaching is that most coaches, even elite ones, lack basic creative thinking knowledge and skills. In-person creative thinking training and workshops appear to have had little impact. Therefore, the research team also hypothesized that more accessible digital tools that support creative thinking would provide coaches with more the creative thinking knowledge and skills.

This case study reports the key design research process challenges, outcome and lessons learned during and from the development and use of four versions of one new digital tool. The tool, called Sport Sparks, was designed to be used across organizations and sports by elite coaches. The lessons learned also have implications for creative thinking in other professional work domains such as social care and workplace health-and-safety, where digital tools have been shown to provide creative thinking knowledge and skills that professionals lack (e.g., [59,34]).

2 ELTE SPORTS COACHING

Elite sports take place at the highest level to win prestigious competitions with the highest levels of skills, strategies and team performance. These competitions include the Olympics Games, FIFA World Cup and English Premier League. Coaching at these levels involves preparing high-performance athletes and/or teams to compete and win prestigious competitions. It can take many forms, and coaches fulfil a wide range of coaching roles that include strength-and-conditioning, the management of nutrition, and providing physiotherapy.

Although little reported evidence of creative thinking applied to elite sports coaching is available, the need for it to improve athlete performance has been established. E.g., creativity was associated with scoring more goals in later rounds

of elite football tournaments [26] and younger people engaged in sports were trained successfully in divergent thinking abilities, tactical creativity and creative thinking [26]. By contrast, reports of creative thinking by professional coaches of elite athletes are fewer, and there have been no reports of digital tools that support coaches to think more creatively. Two identified exceptions were the adoption by UK Sport of creative thinking methods based on rapid trial-and-error of ideas that had a positive impact on medals for Team GB at the 2012 Olympic/Paralympic Games [22], and the use of the CPS structured creative thinking process [23] by 45 strength-and-conditioning coaches at the English Institute of Sport after the 2016 Olympic Games to resolve coaching challenges [57]. However, the research team's preliminary discussions with coaching bodies revealed these to be rare exceptions in elite sports coaching.

Established models of creativity provide us with some possible reasons for the lack of creative thinking in elite sports coaching. While most coaches have expert domain knowledge and are motivated intrinsically to coach well, most lack the creative thinking skills needed to create regularly [3]. Most are also driven by extrinsic rewards (e.g., competition results) often associated with less creative behaviour [3]. Indeed, most coaches are time-poor and under pressure to produce quick results – two pressures that leave little space for creative thinking. Moreover, multiple studies of sports coaching behaviour revealed that many coaches have higher levels of self-confidence combined with lower levels of self-awareness, which was associated with more habitual thinking, less critical thinking and little collaboration beyond existing networks [1,13]. This habitual thinking has been characterized as *unthinking, unchallenging, and uncritical* [37]. As a consequence, most coaches continue to use established coaching practices rather than adopt new ones [49] with naturalistic thinking styles that rely on past experiences rather than external problem-solving techniques or tools [1]. Knowledge from sports science coaching bodies and resources such as academic research and popular science is rarely used [37]. Instead, most coaches used personal experiences and knowledge from their immediate coaching networks [37], leading to potential confirmation bias and reinforcing how coaches think and do [8].

On the other hand, these studies of sports coaching behaviour also revealed that, when prompted, motivated coaches could use critical thinking styles successfully [1], and coaches with more resources (e.g., more knowledge about training practices) were more likely to be successful problem-solvers than those with less [37]. This suggested that digital guidance that provided sports coaches with creativity knowledge could positively change their creative problem-solving behaviour. It revealed a possible opportunity for a new digital creativity support tool.

3 EXISTING DIGITAL CREATIVITY SUPPORT TOOLS AND THEIR APPLICATIONS

Digital creativity support tools have been the subject of research and development for 30 years in diverse artistic, scientific and professional domains. Most have supported the generation of pro-C and little-c creative outcomes and used different forms of interaction to help people to create (e.g., [28,56]). Tools supported creative thinking in science and engineering, e.g., new tabletop visualizations to support biological discoveries [58], education [5], and collaborative design work (e.g., [4,12,16,21,31,43]). Others supported professionals working in creative sectors, e.g., for collaborative editing in location-based television production environments [6], performance art in theatre [20] and resolving health-and-safety risks in manufacturing [34]. However, there has been little long-term uptake of these tools. Indeed, a review of papers reporting them [42] revealed three limitations of the existing research. The first was the lack of longitudinal studies of tool use in-situ. Most of the reported evaluations of digital creativity support tools were short-term, and took place only in controlled settings [42]. The second was the absence of expert users. Most of the reported evaluations involved novices, which limited the validity of the findings [42]. And the third was an evaluation focus on the usability rather than the creative effectiveness of the tools [42]. By contrast, this case study sought to overcome these limitations with new design research that investigated the longer-term use of one tool by expert practitioners to produce more creative thinking and outcomes in one

professional domain outside of the creative industries – elite sports coaching. It reports eight lessons learned from the co-development of the new tool with elite sports coaches. Even though digital technologies in elite sports have become commonplace, e.g., in the forms of video assistant referees [48], machine learning to improve athlete training [19], wearables that collect athlete data [52] and training analyses using video replays [51], none appear to have been co-developed with elite sports coaches. This case study also sought to fill that gap.

4 CO-DEVELOPING WITH ELITE SPORTS COACHES

The research team applied a design science approach [55] that investigated multiple prototypes of an artefact – Sport Sparks – designed to interact in and with problem contexts to improve something in that context – problem solving by elite sports coaches when coaching. The team learned quickly that elite coaches had little time to be observed or interviewed, so novel digital prototypes were developed for the coaches to engage and spend more time with, an approach that also enabled the team to explore what was and not possible with the available data and algorithms and not over-promise.

To kickstart co-development, one professional coach who was co-opted into the team reached out to access elite coaches and sports organizations. The first team activities took place with elite coaches from the English Institute of Sport, an organization that provided sport science and medical support services to elite Olympic and Paralympic athletes. Subsequent activities involved professional coaches working at different English football clubs including one English Premier League club and Sunderland AFC, the largest club in the English Championship. Activities also took place with leading coaches at UK Coaching and Sport England. None were paid to participate, and all volunteered to take part. Preliminary interviews and workshops revealed that the less-experienced coaches – typically graduates in sport science with less than five years of professional coaching experience – were more likely both to use and to benefit from digital support for creative thinking. To guide Sport Sparks co-development with them, the team created two coach personas. E.g., *Eric is in his mid-20s, has three years of professional coaching experience, and was committed to self-development and working independently. However, for more complex challenges he preferred to bounce ideas off others in-person. A core need was to illuminate his blind spots, and he would use a digital tool in lighter periods on his mobile phone if reminded and he experienced value from this use first-hand. The two barriers to using the digital tool were busy coaching periods and forgetting that it was available to use*. The needs of this persona were typical of the interviewed coaches – to explore and resolve challenges, sometimes before discussing them with more experienced colleagues or attending multi-disciplinary team meetings about athlete challenges.

Subsequent co-development work consisted of short design-and-test cycles, some of which were preceded by observations, interviews, and short workshops with coaches. One uncovered constraint was how coaches perceived creative thinking and its role in coaching. Therefore, selected coaches were interviewed to collect examples of creative thinking when coaching (e.g*., involving spouses who prepare food at home to improve the stamina of their athlete partners*) and informal uses of digital apps (e.g., the *Creative Whack Pack*) that were reported to support idea generation for coaching.

The first cycle produced a preliminary version of a creative thinking process designed to operate within the constraints of most coaching environments. The process prescribed the sequential use of up to four creative thinking techniques that were piloted with less-experienced coaches then specialized to coaching. SCAMPER [44] had been developed in the 1970s from earlier creative thinking checklists [40] and used successfully in multiple sectors including business and engineering. Likewise, constraint removal [38] and heuristic ideation [50] were long-established techniques used widely in different sectors. By contrast the creativity triggers technique was more recent [10], albeit one built on the same principle as techniques such as TRIZ [2] – that many creative outcomes have repeating qualities (e.g., [18]), and directing users to ideas

with these qualities can increase the volume of novel and useful ideas. Examples of solution qualities included *doing more or less of something* and *being more playful to users*.

The research team then designed and implemented digitized support to use each technique. E.g., the tool's support for creativity triggers generated and presented different candidate ideas with qualities associated with creative outcomes specific to sports coaching – outcomes such as *doing more or less of post-training warm down* and *making specific training exercises more playful*. By contrast, the support for heuristic ideation presented pairs of already-generated ideas to guide further ideation. The support was co-developed with expert coaches. E.g., during one 90-minute workshop two senior coaches, each with more than a decade of elite coaching experience in strength-and-conditioning, surfaced 85 different good coaching practices that were used to uncover qualities associated with more creative coaching for strength and conditioning, which in turn were codified into the digital support for the technique [32]. The research team also codified qualities of creative outcomes in other coaching specialisms such as the use of facilities and athlete mental well-being. Over time, it learned to undertake more desk research to understand and codify qualities that were subsequently validated and extended by the team's own coaching experts.

Over several years the research team developed increasingly sophisticated versions of Sport Sparks. New versions were released regularly to elicit quick formative feedback from coaches. Sport Sparks was made accessible as a web application that coaches could use during their work via a simple URL without the need to install it or log in. Most coach feedback was qualitative and acquired using questionnaires (e.g., [32]), workshops and interviews that took place both face-to-face and online (e.g., [35]).

5 FOUR DIFFERENT SPORT SPARKS VERSIONS

Four different releases of Sport Sparks were developed and made available to coaches, and screen grabs from the first and last release versions are shown in Figure 1. More information about each of the four releases is reported in the Appendices. Each version was designed to guide a coach through a creative thinking process of entering a description of a challenge, exploring and selecting sparks generated by the tool to support the four creative thinking techniques, then using selected sparks to form an action plan to resolve the challenge.

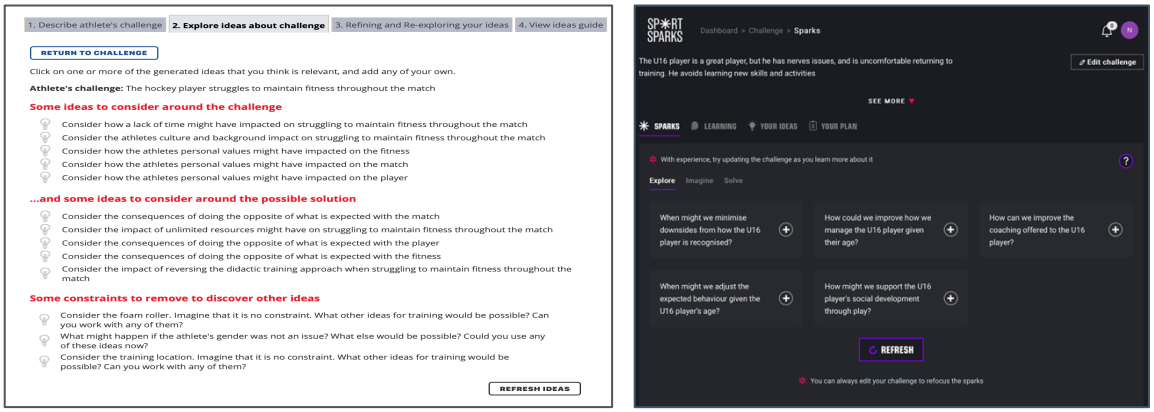

Figure 1. Screen grabs of first (on the left) and latest (on the right) versions of the Sport Sparks tool

The first version supported only two of the creative thinking techniques – constraint removal and creativity triggers – both of which were specialized to strength-and-conditioning coaching. In response to an entered challenge, Sport Sparks

automatically parsed and attributed meaning to the challenge text, then manipulated this text to generate sparks in the form of statements that directed the coach to generate new ideas to solve the challenge. A coach was able to undertake a limited number of tasks using tabs at the top of the page, e.g., to revise the challenge text, refresh presented sparks, and turn sparks into actions in the form of ideas. Ideas could not be saved beyond a session or developed into action plans. The second version refined its support for these tasks, and also retrieved static resources such as academic sports science papers and information from sports blogs related to each entered challenge. Furthermore, in response to coach feedback, it generated sparks as questions rather than statements. E.g., the spark: *think about making the specific training exercises more playful to the cyclists* for the first version was expressed as the question: *how can you make the specific training exercises more playful to the cyclists?* in the second version. These sparks were modified to be more directly applicable to overcome coaching challenges.

By contrast, the third version incorporated multiple changes and new features in response to more coach feedback. The two techniques were specialized further to support creative thinking about a full range of coaching topics including mental wellbeing and managing parents. Coaches were able to set up user accounts, store challenges, and generate action plans to overcome challenges using selected ideas. The interaction design was changed to be responsive to all desktop and mobile web browsers, for ease of use on mobile devices favored by most coaches. The final version guided coaches through the full creative thinking process of describing the coaching challenge, generating possible ideas with which to solve it using any of the four creative thinking techniques, exploring learning resources related to these ideas, managing the ideas, and integrating these ideas into a comprehensive action plan. It incorporated customized creative thinking guidance about athletes (e.g., athlete *physical wellbeing* and *motivation*), their processes (e.g., their *nutritional intake*, *rehabilitation activities* and *working with coaches*, their environments (e.g., their *home life* and *team relationships*) and their competitions (e.g., *the opposition* and *locations*). It also enabled coaches to auto-generate both ideas and action plans through the integration of APIs to GPT-3.5 into the tool. This final version to support the Sport Sparks creative thinking process integrated technologies for natural-language processing, heuristic reasoning, creative search and generative AI.

6 EVALUATIONS AND LESSONS

Elite coaches working in different sports used all four versions of Sport Sparks and provided both formative and summative feedback using both questionnaires and semi-structured interviews. E.g., one evaluation with 22 professional coaches with different levels of experience [32] revealed that 14 were extremely certain or very certain that Sport Sparks supported them to generate alternative views on athlete challenges, e.g.: "*Having time to go through a process such as this allows other perspectives to be explored and time to think about the problem(s) through a different lens…*", and 15 reported being either very or somewhat certain that the tool supported them to discover alternative options, e.g., "*One of the ideas forced me to think and immediately gave me an idea to attempt to tackle the problem in a different way*". In another evaluation 10 professional coaches at the English Premier League football club [35] reported that Sport Sparks supported new idea generation. E.g., one coach claimed that the sparks "*challenged my thinking to think a little bit wider with some things. I had narrowed it down in my head and put the blinkers on and I said its sort of this sort of problem as opposed to thinking about others ways I could approach the issue … So, it was very helpful*". Another claimed "*I think it gave some more clarity on stuff. Like this is the main focus and this where we should think around more than anything. I don't think it perhaps generated new ideas. It perhaps was 'I thought this was a direction we should be going in*'". More details are available in [32,35]. By contrast, the remainder of this case study reports eight key lessons learned by the research team about how to implement more effective digital tools for creative thinking in elite sports coaching. The lessons are listed in Table 1.

Table 1: Key lessons learned to implement more effective digital tools for creative thinking for elite sports coaching, related to each of the four release versions of Sport Sparks

Feature/lesson	Sport Sparks v1.0	Sport Sparks v2.0 - v4.0
Frame coaching work as creative problem solving	++	++
Describe the tool's creative directions as questions		++
Digitize support for established creative thinking techniques	++	++
Codifying each technique's creative guidance as heuristic knowledge	++	++
Design the experience around an established creativity model	++	++
Maximize tool automation to generate ideas and action plans		++
Maximize user control over the tool's automation	++	++
Use practical workshops and non-digital guidelines		++

Each lesson and some of its consequences are unpacked in turn.

6.1 Frame coaching work as creative problem solving

Early in the co-development process the research team found that the term 'creativity' was often problematic in elite sports coaching. Although, e.g., creativity was a core value of coaching at Sunderland AFC and UK Coaching had adopted it as one of its six coaching components [53], interviews revealed that the term *creativity* might alienate coaches due to its association with the arts rather than sports science, even though some senior coaches actively encouraged informal creative thinking by their less experienced colleagues. Therefore, Sport Sparks was positioned as a digital means to support more creative thinking when problem solving to overcome coaching challenges, rather than a tool about creativity. Most coaches who subsequently provided feedback on Sport Sparks accepted this positioning. Indeed, many reported being less resistant to adopting creative thinking in their coaching work than they were to adopting new digital tools.

6.2 Describe the tools' creative directions as questions

The second and subsequent versions of Sport Sparks presented the machine-generated sparks as questions, in response to coach feedback that the instructions implemented in the first version were too prescriptive for professional and motivated coaches. Most subsequent feedback on the sparks as questions was positive, and coaches worked with them without raising further issues. Indeed, in version v4.0, the questions provided an intuitive and effective counterpoint to the auto-generated coaching ideas that were presented as alternative answers to each question. This presentation of creative guidance as questions differed from most creative problem-solving techniques that present their guidance in the form of instructions, e.g., checklists (e.g., *minimize* and *magnify*)) [40], guidelines (e.g., *substitute* and *combine*) [44] and principles (e.g., *segment* and *take out*) [2]. The same was true for other digital tools, which presented creative guidance as information in text or visual forms [27,33,45,54,56] rather than as questions. Instead, Sport Sparks was more similar to the SonAmi tool for authors. Son Ami was an interactive coaster that voices selected text written by an author to challenge and reflect on it [7] The research team's co-development of Sport Sparks with coaches revealed a possible need to rethink creative guidance so that it acknowledges rather than challenges the domain expertise and motivation needed by professionals to create more regularly [3].

6.3 Digitize support for established creative thinking techniques

There were two reasons for digitizing Sport Sparks was designed to digitize support for existing tried-and-tested creative thinking techniques. The first was to build on these established good practices. The second was to free up research team resources to focus on developing effective digitized support. Subsequent co-design and evaluation activities revealed that

most coaches understood and were able to use each of the techniques in digitized forms without help, although some individual preferences for one technique over others were reported. This contrasted with most reported digital creativity support tools (e.g., [27]) that did not support established creative thinking techniques. The research team observed that its decision to implement established good creative thinking practices appeared to overcome most barriers to the acceptance and use of the digital support. Indeed, coaches again expressed more concerns about using the digital tool on their mobile devices than about working with the techniques. Furthermore, the team's decision to digitize established creative thinking techniques provided opportunities to evaluate their acceptability and usefulness before digitizing them using low-cost paper prototypes that could be modified and re-evaluated quickly during the co-development process.

6.4 Codifying each technique's creative guidance as heuristic knowledge

To digitize support for each creative thinking technique in Sport Sparks, the research team codified rules that combined heuristic knowledge extracted from the four creative thinking techniques with procedural knowledge extracted from a wider set of creative thinking methods. Alternative knowledge representations such as cases (e.g., [29]) and deep-learning algorithms to generate knowledge dynamically at run-time (e.g., [30]) were both rejected due to the lack of available sports coaching cases or homogenous training datasets about creative outcomes in coaching. By contrast, the team's codification over of 600 independent heuristics (e.g., *be more flexible* and *imagine what your role model would do*) enabled it both to explain and to control the automated sparks generation, which in turn made more attractive to sports organizations than alternative less transparent approaches such as large language models and generative AI [OPE]. Indeed, after the release of GPT-3, transparency and human control over the digital tool's reasoning emerged as two essential requirements for elite coaching organizations that made a difference between acceptance and rejection of the technology. Moreover, the tool's natural language processing and heuristic reasoning capabilities controlled all inputs to GPT-3, thereby removing the need for any explicit prompt engineering by coaches.

6.5 Design the experience around an established creativity model

The research team developed Sport Sparks to implement one published model of creative thinking – the structuralist model [46]. This model defined creative thinking as a systematic process of structured information searches followed by deliberate idea generation (e.g., [41]) – one common to many structured creative thinking methods (e.g., [15,17,23]). Not only did this model ensure a more consistent design across the four versions of the tool, but also it appealed to many coaches who sought in their coaching work to develop and implement repeatable coaching methods. For some coaches it demystified the creative thinking processes. Indeed, given the tool's more creative uses of digital information about coaching problems and solutions, Sport Sparks was presented simply as a tool to manipulate this information more effectively, rather than to support more abstract notions such as cognitive or social creative thinking [45].

6.6 Maximize tool automation to generate ideas and action plans

To support coaches to think more creatively, Sport Sparks was designed to automate activities associated with the four creative thinking techniques, consistent with Shneiderman's first fresh idea for human-centered AI [47] and uses of computational creativity outputs such as images (e.g., [14]), music (e.g., [11]) and stories (e.g., [25]). The research team's observations and interviews revealed that most coaches were time-poor and spent most time on training grounds, so a design decision was made to maximize the auto-generation of and minimize the inputs of text by coaches. As a consequence, once a challenge had been entered, Sport Sparks presented auto-generated spark questions and resources that coaches only needed to browse and select, auto-generated partial answers to spark questions that coaches only needed to

complete, and in version 4.0 ideas auto-generated through invocation of the GPT3.5 API. This final version also auto-generated a draft action plan that coaches could review and edit using as inputs the challenge description and selected ideas rather than generate from scratch. Most coaches accepted this level of automation, and many worked effectively with the auto-generated sparks to discover new perspectives on challenges and ideas to solve them, sometimes reporting that the sparks and ideas also reassured them about their own new ideas for coaching. This directed some coaches to discover new information and adopt more critical thinking styles, both of which were associated with being more successful coach problem-solvers [1,37].

6.7 Maximize user control over the tool's automation

Another possible reason for the acceptance of Sport Sparks by most coaches was that it provided them with full control over the timing and direction of the automation, which was also consistent with Shneiderman's first fresh idea for human-centered AI [46]. Again, most coaches quickly accepted this level of control, and several working at the English Premier League club were positive, with one reported liking the way the tool division of the sparks to 360-degree views of challenges. Indeed, the research team observed that the combined digitized support and auto-generated content sometimes provided important handrails that guided coaches to use creative thinking techniques in ways not possible if each technique had not been codified in digital tool support.

6.8 Use practice workshops and non-digital guidelines

In response to observations that coaches were more open to creative thinking than using digital tools in their coaching, the research team also developed a set of non-digital touchpoints aligned with the tool's support. These touchpoints including workshops that walked small groups of coaches through each creative thinking technique as a means of demonstrating the equivalent digital support, printouts that described how to use each technique without digital support, and booklets of coaching sparks which coaches could browse to generate ideas. Combined, these touchpoints provided entry points to the service that were simpler than the digital tool. E.g., coaches at Sunderland AFC were initially more open to these more familiar non-digital artefacts that the tool, and this provided an effective entry point to the tool later on.

7 CONCLUSIONS AND LIMITATIONS

To conclude, this case study reports the process, outcome and selected lessons from designing a new digital experience for elite sports coaches from different organizations. The outcome, Sport Sparks, was a new co-creative AI tool that guided elite coaches through a process of describing a coaching challenge, generating possible ideas to solve it using creative thinking techniques, exploring learning resources related to these ideas, managing the ideas, and integrating these ideas into an action plan that could be auto-generated for coaches to review. The reported lessons learned by the research team during the tool's co-development have the potential to instruct other computer-human interaction practitioners in both how to co-develop digital tools with elite coaches (e.g., *share early prototypes to gain their attention*) and how to design co-creative AI tools acceptable to professionals and their organizations (e.g., *present creative guidance as questions*, *direct generative AI using automated heuristic reasoning extracted from creative thinking techniques*). Some insights from these lessons are already providing the baseline for the wider rollout of Sport Sparks over the next six months in several other elite sports organizations and clubs.

This case study also advances the state of practice in several directions. It reports one of the first computer-human interaction studies with elite sports coaches, and revealed challenges when co-designing with elite coaches who are time-poor and only use digital technologies occasionally. It also advanced digital creativity support research by developing a

new tool that are claimed to overcome three limitations of existing research reported in [42]. Unlike the previous research, Sport Sparks was deployed in uncontrolled settings for longer periods of time and used by expert professional users working outside of a recognized creative industry. It was also one of the first co-creative AI tools to explore its impact on the creative thinking of these users. Although not reported here, the Sport Sparks' architecture also demonstrated one means of integrating natural-language processing, heuristic reasoning, creative search and generative AI technologies to provide value to professional users.

To direct the case study, the research team posited two hypotheses related to the rollout of Sport Sparks in different coaching organizations. Although the systematic collection and analysis of data with which to investigate these hypotheses was not reported, the previous evaluations [32,35] and current collaborations with elite coaches do not provide evidence to reject the hypotheses. The first stated that more regular uses of creative thinking techniques in elite sports coaching would result in more pro-C, mini-C and little-c outcomes, with possible positive effects both the coaching and performance of athletes and teams. The evaluations summarized in this case study provide indirect evidence of mini-C and little-c outcomes based on direct reports from coaches, even though the effects of these outcomes on athlete and team performance have yet to be explored. The second stated that more accessible digital tools would provide coaches with more creative thinking knowledge, and coach use of both digital and non-digital guidelines was both observed and reported to direct their creative thinking.

The case study also has the potential to be important in other ways. More coach creative thinking, especially about, e.g., athlete mental and physical well-being and their home life can both broaden their understanding of challenges faced by athletes and contribute to reducing future occurrences of athlete abuse in professional sports. Sport Sparks could also be applied to improve coaching at multiple levels beneath elite sports, e.g., in amateur athletes and college sports. Less well-resourced amateur coaches often lack more of the knowledge and skills needed to overcome challenges effectively. Therefore, a version of Sport Sparks for amateur coaches could provide valuable handrails, knowledge and resources with which to guide and direct everyday problem solving. Finally, the case study can also provide insights about the importance of creative thinking in other non-creative sectors struggling with productivity and/or growth – sectors such as business, or health and social care. Broader lessons are currently being applied to develop and rollout other co-creative AI tools, e.g., how small- and medium-sized businesses can think more creatively about their business strategies.

Finally, of course, this single case study is subject to numerous limitations, some of which are reported here. The co-design activities and evaluations were open to different response biases, in particular providing responses consistent with research team expectations. The research team observed notable differences in coaching operations, resources and digital uptake between elite football clubs playing in the same league, so Sport Sparks might align better with some club operations than others. Furthermore, implementing Sport Sparks across the operations of an elite sports organization takes time, and the current case studies will evolve over years rather than months, especially to explore possible effects of more creative thinking in coaching on athlete or team performance. Therefore, we present the case study as one that has progressed over four years, but will continue for perhaps another three or four.

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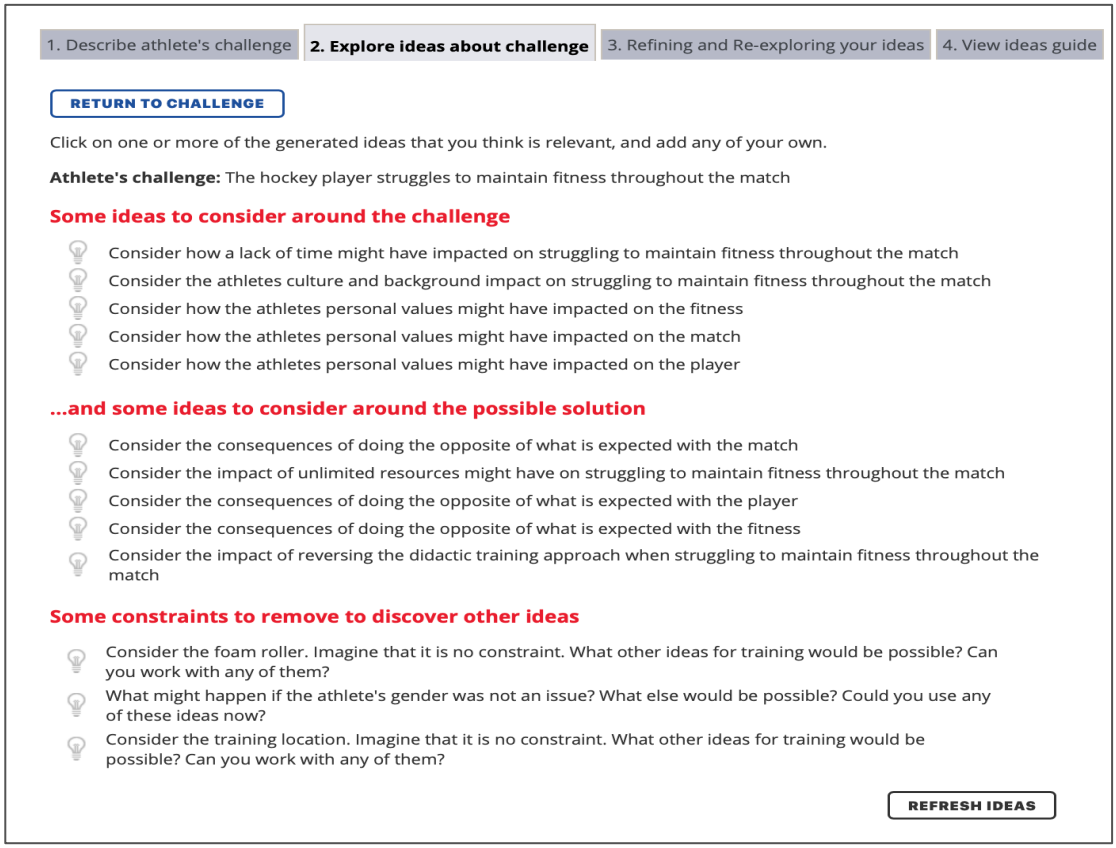
APPENDICES

The appendices provide more information about each of the four release versions of the Sport Sparks tool.

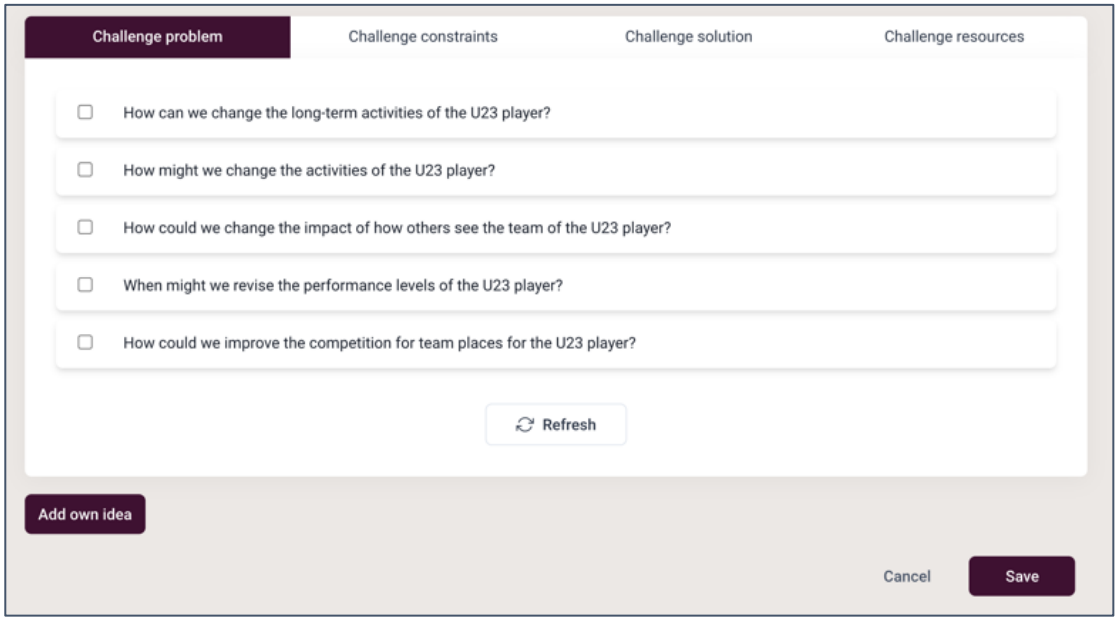
A.1 Sport Sparks version 1.0

A screen grab of version 1.0 of Sport Sparks is shown below. This first version was the simplest of the four. It was developed to enable coaches to use and provide feedback on core capabilities such as the automatic generation of sparks from an entered challenge description and use of these sparks to generate candidate ideas. It provided support for two of the four creative thinking techniques in the process – constraint removal and creativity triggers. Both of these techniques were specialized primarily but not exclusively to strength-and-conditioning. Each set of generated sparks was listed together as shown in the screen grab. In response to a challenge that a coach typed into a text box, the tool automatically parsed and attributed meaning to the challenge text, then manipulated this text to generate sparks in the form of statements (*e.g., Consider how the athlete's personal values might have impacted on the match*) that directed the coach to generate new ideas to solve the challenge. The sparks generation algorithm was designed to produce both sparks that made immediate sense to the coach that could be applied to overcome the challenge, and sparks that did not. Coaches were able to undertake a limited number of tasks via the tabs, presented as a sequence of tasks at the top of the page, e.g., to revise the challenge text, refresh presented sparks and turn sparks into actions. Ideas could not be saved beyond a session or developed into action plans.



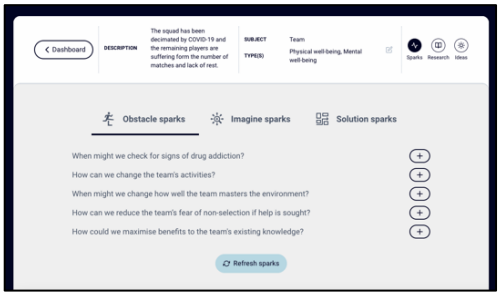
A.2 Sport Sparks version 2.0

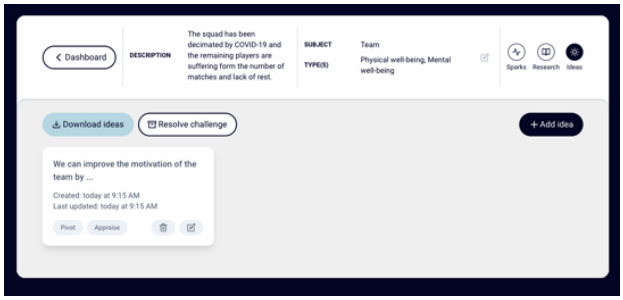
A screen grab of version 2.0 of Sport Sparks is shown below. This version was developed to be more complete and more usable by coaches than v1.0. It was developed to explore and collect feedback from coaches about the tool's key capabilities. It still supported two of the four creative thinking techniques in the bespoke process – constraint removal and creativity triggers – but was capable of generated a wider range of sparks for each technique due to an expansion of the heuristics that codified creative thinking and coaching knowledge. Unlike in the first version, the sparks generated to support each of the two techniques were presented in different tabs that coaches could choose between, and as questions rather than statements. Otherwise, this version's generation of sparks was similar to the first. In response to an entered challenge, it automatically parsed and attributed meaning to the challenge text, then manipulated this text to generate sparks in the form of statements (*e.g., How might we change the activities of the U23 player*) that directed the coach to generate new ideas to solve the challenge. Furthermore, under the new resources tab, the tool retrieved static information resources such as academic sports science papers and information from sports blogs related to each entered challenge. In contrast to the first version, the sparks generation algorithm was designed to produce sparks that made immediate sense to the coach and could be used to overcome the challenge, at the exclusion of sparks that did not. Ideas still could not be saved beyond a session or developed into action plans.



A.3 Sport Sparks version 3.0

Two screen grabs of version 2.0 of Sport Sparks are shown below. This version incorporated multiple changes and new features to the second version in response to more coach feedback. The two techniques were specialized further to support creative thinking about a full range of coaching topics including athlete mental wellbeing and managing parents. Coaches were able to set up user accounts, store challenges, and generate action plans to overcome challenges using selected ideas. Each registered coach was able to manage information about challenges, ideas and possible actions via a personalized dashboard. The interaction design was changed to be responsive to all desktop and mobile web browsers, for ease of use on mobile devices favored by most coaches. The left-side screen grab shows the redesigned presentation of the generated sparks for the same two techniques underneath a header that provides basic information about the challenge and functions to use with respect to that challenge. The right-side screen grab shows the management of ideas (in particular the first idea) generated in response to the challenge.





A.4 Sport Sparks version 4.0

A screen grab of version 4.0 of Sport Sparks is shown below. This version guided coaches through the full creative thinking process of describing the coaching challenge, generating possible ideas with which to solve it using any of the four creative thinking techniques, exploring learning resources related to these ideas, managing the ideas, and integrating these ideas into a comprehensive action plan. It incorporated customized creative thinking guidance about athletes (e.g., *athlete physical wellbeing* and *motivation*), their processes (e.g., their *nutritional intake*, *rehabilitation activities* and *work with coaches*, their environments (e.g., their *home life* and *team relationships*) and their competitions (e.g., *opposition* and *locations*). It also enabled coaches to auto-generate both ideas and action plans through the integration of APIs to GPT-3.5 into the tool. This final version to support the Sport Sparks creative thinking process integrated technologies for natural-language processing, heuristic reasoning, creative search and generative AI.