Sport Science Meets Cycling HCI: Rethinking Visualizations for Cycling Performance Metrics

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Many cyclists, from commuters to amateur competitors to professionals, aim to get stronger and faster on the bike. The use of technology in cycling has transformed the way these riders approach training. They can now easily access data such as speed, distance, heart rate, power and more, empowering them to understand their capabilities and track their progress over time. However, the design and display of popularized performance metrics in the cycling community may inadvertently encourage cyclists to push too hard or to underestimate their efforts, both potentially leading to suboptimal performance outcomes. This position paper examines several commercially available performance metric displays and highlights the need for research on how to design interfaces that translate complex physiological metrics into intuitive visualizations that avoid the pitfalls of today's technology. We hope to influence the conversation in Cycling HCI toward the intersection of HCI and sport science and work to create more informed user-friendly designs that cyclists can rely on to improve their performance and enjoyment of the sport.

CCS Concepts: • **Human-centered computing → Visualization design and evaluation methods**.

Additional Key Words and Phrases: Cycling technologies, sports science

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1 INTRODUCTION

In recent years, technology has reshaped the landscape of cycling, transforming the ways riders train and engage in the sport [7]. Metrics once exclusive to elite athletes with expert coaching are now readily available thanks to wearables, on-bike sensors, and cycling-specific computers. In particular, wearable technology is increasingly granting everyday cyclists unprecedented access to performance data derived from speed, distance, heart rate, power and more [9]. Commercial platforms such as Training Peaks[1], Whoop[2], and Strava [3] have developed widely used visualizations for these metrics, helping cyclists turn raw data into actionable insights. Millions of cyclists worldwide use these platforms to monitor and optimize their performance to achieve their goals [4, 6].

However, as cyclists immerse themselves in this data, there is a growing concern about the misinterpretation or mismanagement of popular performance indicators [18]. To understand this concern, we turn to the body of literature

[1]https://www.trainingpeaks.com/
[2]https://www.whoop.com/us/en/
[3]https://www.strava.com/

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in sport science, which has established that *stress*, *recovery*, and *training load management* are fundamental concepts important to enhancing performance and preventing burnout or injury [16]. *Stress* refers to the physical demands placed on the body during exercise [5]. This stress is not inherently negative; it is necessary for promoting adaptations that lead to improved fitness and performance . *Recovery* is the important counterpart to stress. It represents a time of restoration following exertion [10]. Training stress breaks down muscle and uses up energy, while recovery allows for repair and rebuilding, ultimately enhancing fitness and strength. Finally, *training load* refers to the cumulative impact of stress from activities and the following recovery time. Putting these concepts together, the best training approaches rely on *training load management* to optimize the balance of stress and recovery. Good training load management often involves systematically varying key dimensions of stress including intensity ("hard" versus "easy") and volume ("long" versus "short") to allow for adequate recovery and adaptation, which ultimately makes a cyclist stronger and faster [8]. However, as the next section details, many of the most popular metrics cyclists rely on through commercial platforms focus on particular aspects of training stress and recovery without considering the broader picture of training load management.

While many users benefit from basic applications or gamification strategies [19], they may be easily drawn in by the allure of personal bests and virtual competitions, and risk succumbing to the trap of overexertion (too much training stress and too little recovery). Conversely, advanced amateurs often find themselves grappling with raw statistics or insufficient basic metrics that fail to support their complex motivations, hindering their ability to refine their training strategies effectively [19, 23]. Designs and visualizations that leave cyclists struggling to make sense of the information or encourage the relentless pursuit of peak metrics, personal bests, and virtual competitions may inadvertently result in adverse outcomes such as diminished performance, burnout, or even injury. There is a pressing need for research to investigate the ways in which performance metrics can be better displayed to cyclists, empowering them to reach their goals while avoiding the common pitfalls mentioned above.

The HCI research community has an important role to play in filling this research gap, having turned its attention increasingly to the realm of sports, recognizing it as a rich domain for both learning and innovation [13, 15]. For example, in recent research on runners, Menheere and colleagues found that performance and competition visualizations play a crucial role post-exercise [14]. These visualizations served to amplify motivation for further exercise, stimulating the desire for self-improvement and competition with others. Meanwhile, the bulk of cycling HCI has focused on rider safety [3, 12, 22], navigation [17], and communication with vehicles or other hazards [2, 21]. The design of novel displays for cycling is an important aspect of these investigations, including our own lab's recent work on displaying heart rate for collaborating cyclists [1]. This position paper aims to expand the conversation to the intersection of CyclingHCI and sport science, to examine opportunities for novel interfaces and displays that help cyclists achieve their training goals.

2 WIDELY USED METRICS FOR CYCLISTS

For deeper exploration, we provide a series of scenario-based examples featuring popular commercial platforms that have a significant user base within the cycling community [4, 6]. These examples illustrate how cyclists can be affected by these metrics in their training journey.

Stress Score. One of the most widely used metrics for cyclists when training is a measure of stress or strain during a workout. One example of such a metric is Training Stress Score (TSS), developed by Training Peaks, which offers a straightforward yet scientifically informed method to gauge how a ride or workout affects the body, considering both

intensity and duration of the effort[4]. It operates like a points system: the harder and longer the ride, the higher the TSS. So a TSS of 100 would mean a cyclist accumulated a significant amount of "training stress" for a 2-hour ride. The graphical presentation of TSS, within the Training Peaks software, allows users to visualize their workload over time. Figure 1 shows a TSS display from TrainingPeaks. In the display, each red dot represents a daily TSS score, reflecting the impact of a single ride, while the lines represent rolling average TSS values to track trends over time and monitor training load effectively.

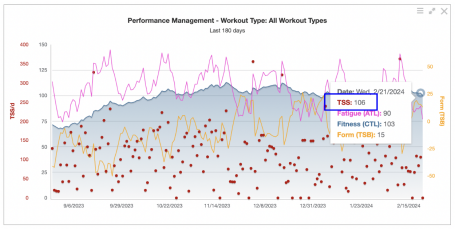

Fig. 1. Training Stress Score (TSS) Display on Training Peaks Platform

However, when interpreting trend lines and numerical scores, there is often a tendency to associate an upward trend and higher numbers with progress and improvement [20]. Consider a cyclist who becomes fixated on achieving peak TSS targets: this cyclist may become excited to have achieved a TSS of 200 for a single ride and sets their sights on achieving an even higher TSS in a future ride, potentially disregarding signs of fatigue and overexertion. With the belief that higher numbers equate to better fitness, they might persist through intense workouts without considering their recovery needs. The platform's display, lacking contextual information or guidance beyond dots and lines representing TSS, may further reinforce this fixation. As a result, the cyclist risks overuse injuries and burnout due to insufficient consideration of overall training load management [8].

Recovery Score. Another widely used metric by cyclists is recovery score, an indicator of how well-rested and recovered their cardiovascular system is. A popular commercial platform that displays and tracks a cyclist's recovery score over time is Whoop. Whoop relies on a proprietary wearable fitness tracker that detects physiological measures such as heart rate, heart rate variability, and respiratory rate to provide a user with a daily recovery score. The recovery score is shown on a scale from 0-100%, with higher scores indicating better recovery. This score is also color-coded: red means inadequate recovery, yellow means moderate recovery, and green represents optimal recovery for physical activity. These colors offer cyclists a quick visual cue to understand their current recovery status, empowering them to adjust their training intensity and prioritize activities accordingly. Figure 2 shows a user's Whoop recovery score over a seven-day period.

This display, and the associations many users have with a high score and a green bar, can lead to misconceptions on the part of the user. Recall that progress in fitness requires periods of stress followed by adequate recovery [16]. If a cyclist becomes too focused on achieving high recovery scores through their Whoop tracker, they might prioritize restorative activities at the expense of intense training. This approach will lead to too little training stress, and eventually a decline in fitness. In fact, occasional yellow and red recovery scores from Whoop are necessary for adaptation and growth. A promising open area of research for cyclists is how to better display recovery scores in a way that emphasizes the importance of training

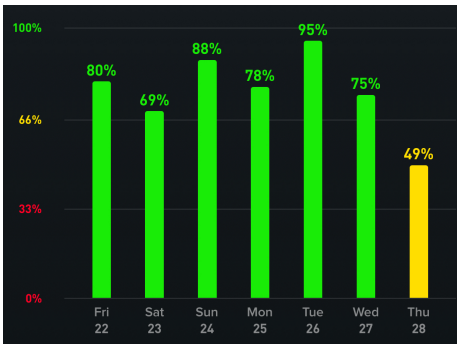

Fig. 2. Recovery Score Display on Whoop Platform

[4]https://help.trainingpeaks.com/hc/en-us/articles/204071944-Training-Stress-Scores-TSS-Explained

stress and recovery, and provides positive visual feedback when a cyclist's recovery scores vary with a well managed training load.

Leaderboard Score. Research shows the positive impact of social support on exercise adherence and enjoyment [11]. Furthermore, studies have shown that incorporating elements of competition into fitness activities further enhances motivation and performance [24]. Leaderboards display the fastest riders to complete certain routes, and comparing oneself to the performance of others is a metric that allows users to engage in (mostly) friendly competition. A popular commercial platform that uses leaderboards is Strava, on which cyclists can track and post their rides, connect with others, see where they compare on the leaderboards of their favorite routes, and compare their weekly mileage with other riders. Figure 3 shows a Strava leaderboard display that ranks the user among their peers for total weekly completed mileage.

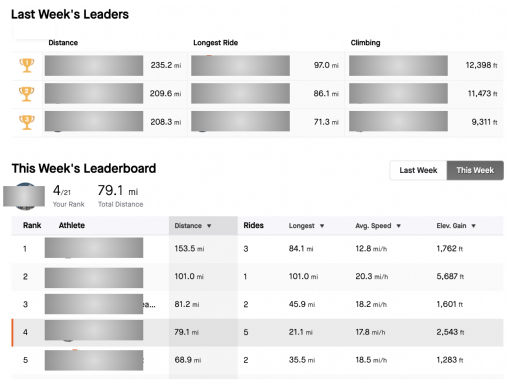

Fig. 3. Leaderboard Score Display on Strava Platform

While these design elements can inspire cyclists to push themselves, they might also fuel a fixation on achieving top rankings, such as securing the highest spot for weekly mileage among their peers. This competitive pursuit may influence a cyclist to push themselves beyond their limit, extending rides to accumulate more miles and climb higher on the leaderboard. Despite short-term success in achieving impressive mileage, this relentless pursuit of peak metrics can result in chronic fatigue and increased susceptibility to illness [8].

3 CONCLUSION

This position paper has examined three popular cycling performance metrics and the ways in which they are displayed in the context of widely used commercial platforms. The authors of this position paper have cumulatively 15 years of experience as competitive cyclists following structured training plans and using the commercial technologies examined in this paper. Moreover, the lead author has 7 years of experience as a sport scientist supporting professional cycling teams. The pitfalls discussed in this position paper are not hypothetical; both authors have witnessed them firsthand among novice and highly experienced cyclists alike. It is our belief that even state-of-the-art displays may be misleading many cyclists to suboptimal outcomes, and countless others may potentially not continue in the sport due to the emotional and physical toll of an unbalanced training load. To the best of our knowledge, there has been little to no investigation from an HCI research perspective of the extent to which state-of-the-art performance metric displays may lead to these negative outcomes.

The Cycling HCI research community is presented with a unique opportunity to integrate these insights into better designs. By understanding how cyclists interact with performance metrics, HCI researchers can develop solutions that prioritize both performance enhancement and well-being. It is also crucial for HCI researchers to work closely with coaches, sports scientists, and other experts who can provide context, guidance, and individualized feedback on metrics. By embracing a user-centered approach and leveraging these lessons learned from cycling, we hope to empower cyclists to achieve their goals in a way that fosters positive lifelong engagement in the sport.

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