

Appendix 9.1 – Future study ideas (beyond those mentioned within thesis):

1. *Circadian rhythms of performance*

One concept that would be fascinating to study within an esports context is the idea of *circadian advantage/ disadvantage*. This concept has appeared frequently within big data (i.e. 10+ seasons) performance analysis of major team sports competitions, such as the Fédération Internationale de Football Association (FIFA) World Cup, Major League Baseball (MLB), National Basketball Association (NBA), National Hockey League (NHL), and National Football League (NFL). A general consensus reached within many such articles (i.e., Charest et al., 2021; Glinski & Chandy, 2022; McHill & Chinoy, 2020; Roy & Forest, 2018; Smith et al., 1997; Steenland & Deddens, 1997; Winter et al., 2009) is that teams travelling westward perform worse than teams travelling Eastward in evening/ night games, as the *biological time of day* for eastward travelling players tends to be closer to a hypothetical performance *peak*, while the biological time of day of westward travelling players is later and thus closer to a hypothetical performance *nadir*. However, the identification of such an effect can be confounded in such analysis by (a) circadian adaptation and (b) the physiological effects of jet-lag, which are generally worse following eastward travel compared to westward travel (Waterhouse et al., 2007). Esports presents as a particularly unique opportunity to explore this phenomenon without such confounders, as the vast majority of esports competition takes place online, where players can play each other competitively in real-time despite being in different time-zones. For example, a player within Ireland could be playing a match at 8PM local time, against an opponent living in Saudi Arabia at 11PM local time. Inferences based on literature exploring cognitive performance measures across time of day, as well as the aforementioned analyses of multiple sporting seasons, would suggest that the player in Ireland is at an inherent advantage, as 8PM is closer to a hypothetical circadian peak than 11PM. However, this is hypothetical, and it remains unclear whether esports performance fluctuates across time of day (and if so, when are the peaks and nadirs?). This is a research idea I invested a lot of time into using in-game Rocket League data derived from ballchasing.com, but unfortunately could not ultimately get to work, due to the lack of data at the time, and bugs related to the recording of time within this system. Nonetheless, I remain confident that such analysis is possible, and could provide great value toward both the understanding of human factors contributing to esports performance but also toward task specificity of circadian/ time of day effects more broadly.

2. *Genetic analysis of esports athletes with respect to chronotype.*

The scores on the Horne-Östberg morningness eveningness questionnaire (MEQ) for the included population of esports players (29 intermediate, 11 evening type) was skewed substantially more toward eveningness when compared to most athlete (Kunorozva et al., 2017; Kunorozva et al., 2012; Lastella et al., 2016; Rae et al., 2015; Smithies et al., 2021) and non-athlete (Kunorozva et al., 2017; Kunorozva et al., 2012) populations reported (but see Osland et al. (2011) for one population (Norwegian university students) with a MEQ distribution similar albeit slight less skewed toward eveningness than that presented here). This skew toward eveningness was accompanied by mean habitual self-reported sleep onset (00:57+1) and wake (09:35) that is substantially later than normally reported for similar age-matched demographics. We note even later mean sleep onset (02:00+1 to 05:04+1) and wake (09:51 to 12:13) times for homogenously previously reported professional esports athlete samples (Bonnar et al., 2022; Lee et al., 2020; S. Lee et al., 2021). What is causing such extreme sleep onset and wake delays (and a presumed skew toward eveningness accompanying)? Is this driven (primarily) by genetic or environmental factors?

A strong case for environmental influence was made by Kunorozva et al. (2017), regarding the MEQ skew toward morningness for South African professional Rugby Union players. This skew occurred despite the prevalence of a genetic factor strongly linked to morningness (the PERIOD3 variable number tandem repeat *PER3*⁵) being no different to the general population. The authors theorised that the skew could be a result of an early morning training culture within rugby union in South Africa, combined with the high physical demands and prioritisation of performance leading to earlier bed and rise times. The same logic could easily be applicable within esports. Esports at a professional level is hallmarked by extremely late (as late as 01:00+1 finish) practice (i.e. scrimmaging) times (Bonnar et al., 2019). Could such late practice times push individuals who are genetically predisposed toward morningness to adopt an evening circadian preference (i.e. forcing one's internal body clock to match the temporal requirements of a certain activity, an act sometimes referred to as *Chronophasing* (Erren and Rieter, 2013; as cited in Erren et al., 2014))? An additional factor is the melatonin suppressing properties of computer monitors (Green et al., 2017; Schöllhorn et al., 2023) (the primary output modality for esports) combined with the highly stimulating nature of esports, likely increasing sleep onset latency and further delaying sleep onset and

wake times. These two factors may work synergistically to push individuals toward an extreme evening preference, hallmarked by particularly late sleep onset and wake times.

A worthwhile line of research may be to explore the relationships between circadian genotype and phenotype within esports athletes, in a similar vein to Kunorozva et al. (2017). This may uncover to what degree evening tendencies of esports athletes are genetically or environmentally determined. If (like in Kunorozva et al. (2017)) genetic markers of circadian preference do not align with circadian phenotype, it would call into question the broadband use of late night training within esports. Conversely, a push toward eveningness within esports which is genetically driving could suggest a self-selection scenario, whereby individuals are potentially selection into or out of esports based on circadian influencing genetic factors.

3. Automated (living) machine learning for meta-agnostic notational analysis in esports

In **Chapter 5**, I presented a strong and repeatable framework for using a modern and powerful machine learning approach to identify performance (PI) and rank (RI) indicators in 1v1 Rocket League. Since the publication of this work in *Scientific Reports*, other published work has shown the utility of other machine learning approaches to identify PIs and/or RIs in other esports. This includes logistic regression (Bialecki et al., 2023) and neural network (D. Lee et al., 2021) based methods for the real-time strategy (RTS) esports *Starcraft II*, gradient boosted regression (similar to the Random Forest approach outlined in **chapter 5**, however differing in CART creation method; Bahrololloomi et al. (2023)) and multiple model/ meta-model (Hitar-García et al., 2023) based approaches for the MOBA game League of Legends (LoL), and gradient boosted classification models for simulated racing (Hojaji et al., 2023). Such analyses will only serve to better understand important in-game factors ultimately contributing to success, and as such, augment training practices for prospective esports players. Within **chapter 5**, I also call for future research to entertain the use of alternate feature importance measures and expand the outlined approach to team-based Rocket League, and while such work has not surfaced within the scientific literature to date, I believe that such work would be highly beneficial to both the Rocket League community, and to the field of data analytics within esports.

One highly promisingly avenue of future work, which is related to but not discussed within **Chapter 5**, is the automation of esports game data extraction, processing, predictive model

building, and feature selection (i.e. real-time machine learning). Such work would allow for easy updating/ improving of PI/RI identification procedures, using a constant live influx of game data. If these steps were well automated (and perhaps developed into a computer program/ software), one could seamlessly be able to find PIs/RIs which are not only constantly updated, but are within any set of constraints. What if an individual wants to know what in-game factors were most predictive of success at their current rank? Or, what if an individual wants to know what PIs were most important within a specific time frame (this idea is discussed in the next paragraph)? Automation and development of such a system is certainly possible, and could be of tremendous benefit to coaches and prospective athletes within whichever esports it is built for.

Regarding the latter hypothetical question, this automation could resolve the issue of *meta-shifts* within esports data analysis. *Meta* is a term used to describe a dominant and popular strategy or set of strategies within an esports (Kokkinakis et al., 2021), and is inaccurately but somewhat fittingly mistaken as an acronym for *most effective tactics available*. Meta-shifts occur far more frequently in esports than traditional sports. This can be attributed to a large degree toward *game patches*, referring to changes of game parameters introduced by game developers (Chitayat et al., 2023). Some traditional sport analogies for this phenomena are the introduction of the three-point field goal in basketball (Jaguszewski, 2020), castling in modern chess (Pratesi, 2008), or more recently, the 50:22 rule in Rugby Union (Scott et al., 2023). On this front, Rocket League is certainly the major esports that is least susceptible to patch related meta-shifts, owing to the games simple design, lack of in-game characters, and likeness to established traditional sports; this is a strength of Rocket League as a target esports for experimental research not discussed within **chapter 5**. However, meta-shifts can also occur without such changes of game parameters, instead perhaps through the learning of more efficient and effective tactics, or as a result of general in-game mechanic improvements over the timespan of a given esports. Regardless of cause, meta-shifts have been identified as a limiting factor for the relevance of esports data analytics performed on static data sets (Chitayat et al., 2023; Summerville et al., 2021). While some efforts have been made toward meta agnostic approaches, they appear limited towards game-type and specific circumstances of meta changes (Chitayat et al., 2023). The automated approach described earlier would completely overcome meta-shift concerns, by seamlessly allowing the analysis of data collected within any desired time frame (i.e. before or after a meta-shift).

4. Cost-benefit investigation of sacrificing sleep for extra practice (grind vs. sleep)

This idea closely resembles research ideas I originally had toward the beginning of my thesis, however did not end up being feasible for the purposes of the thesis. A common practice for many professional esports athletes is to either further practice or stream gameplay (i.e. Madden & Harteveld, 2021) following their already incredible late formal practice (Bonnar et al., 2019). Given how late this occurs, excessive late-night gameplay could easily eat into the sleep opportunity or sleep obtained for esports athletes. This could be compounded (or more readily experienced) closer to a major competition, where players may increase practice frequency in a similar fashion to high school or college students losing sleep due to cramming within one or multiple nights prior to competition.

Does this form of cramming provide any performance benefit compared to obtaining adequate sleep, or conversely, is it actively harmful to in-game performance? This question could be nicely investigated using somewhat of a sleep restriction protocol, if the means and facilities (perhaps a live-in team practice facility) were available, alongside a sufficient amount of players available to participant obtainable (this would be by far the greatest logistical challenge). In such a protocol, players could be randomly assigned to one of two groups. Both groups would complete practice volumes as normal. One group may be afforded an 8hr sleep opportunity, while the other group is only assigned a 5hr sleep opportunity; however the three hour discrepancy is spent actively training within the given esports. We note that this would have to be a multiple day protocol (as one day would be highly unlikely to elucidate any effects, given the null results of ~29hr TSD as described within this thesis).

While such an approach would be fascinating and of extremely high ecological validity (following Orne's definition; Kihlstrom (2021)), there are major logistical boundaries. By far the biggest issue would be the sufficient recruitment and buy in of esports players. This is a notorious issue among research in general aiming to explore human factors in esports, but would be of particularly great difficulty given the participant burden this protocol would create.

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