Wearing Eye Tracking Technology during Batting Practice: Assessing the Experiences of Professional Baseball Athletes

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Abstract   Utilizing wearable technology in sport allows for the collection of motor behavior data during task engagement. This data can be assessed in real-time or retrospectively. Although enriching the scope of performance data, the consequences of wearable technology on the athlete-user, specifically the cognitive effects, has not been fully investigated, hence the purpose of this study.

This qualitative study examines the cognitions of 57 professional baseball players who wore eye tracking technology whilst engaged in batting practice. Their verbal self-reports were framed by temporal context: before-during-after task. Three themes emerged during the pre-task segment: social appearance anxiety, claimed self-handicapping, and curiosity. During the task of batting, verbal behavior contained motivational and instructional overt self-talk while claimed self-handicapping was sustained. The final, post-performance segment was marked by the re-emergence of curiosity from the pre-task period as well as self-evaluation/appraisal.

Given the participants were professional athletes, their performance has greater career implications than amateur competitors. Nonetheless, the verbal behavior elicited while wearing eye tracking technology indicates an awareness of the equipment by the user. This study found cognitive effects from wearable technology; more research is required to understand the scope and nature of those effects on cognitive and motor behaviors.

Keywords   *wearable technology, baseball, self-handicapping, social appearance anxiety, self-talk*

1. Introduction

Sport in today's society is inextricable from technology, from heart rate monitors to complex computerised officiating tools such as HawkEye; a variety of products have been developed with the aim of enhancing athletic performance. The transfer of technological innovations from other industries and disciplines into the sporting domain has been widely accepted by athletes and coaches as invaluable [1]. Such technology ranges from video analysis for the provision of extrinsic visual feedback, to simulated three-dimensional virtual environments that aid training, to biofeedback devices such as heart rate monitors, electroencephalographs (EEG) and the use of eye tracking technology to analyse athletes' gaze. Technology in sport is pervasive.

Eye tracking technology, is an example of wearable technology, a sub-division of micro-technology that is worn by the person, in this case, the athlete, for the purposes of collecting performance data to assess and enhance sport performance [2]. For dynamic sports such as baseball, eye tracking technology allows the coach to see where the athlete is specifically looking as well as the environmental scene captured from a camera mounted on a visor or pair of glasses. The eye tracker also has audio recording. In baseball, for example, this technology is helpful when reviewing visual cues, verbal interactions and the general visual environment (or scene) from the athletes' perspective.

As the development in micro-technologies advance, research into the usability and effect of wearable technologies on performance has attempted to keep pace. A review of 180 studies of human-technology interaction reported a number of problems in measuring usability [3]. These complications range from difficulties in capturing user perceptions of the technology and satisfaction to a lack of quality of interaction with the required outcome measures. Nonetheless, there are both short- and long-term benefits for technology-based feedback to enhance sport performance, particularly in training settings [1]. The short-term benefits include gaining an understanding of otherwise inaccessible variables such as visual calibration and heart rate variability and the long-term benefits include the ability to quantify and track these variables over time.

The use of wearable technology by athletes allows an insight into and measurement of external behavioral variables. This may be viewed as an obstacle or facilitator of performance. One of the explanations for wearable technology being a potential facilitator of performance is the presence of the Hawthorne effect [4]. The Hawthorne effect, a phenomenon discovered by the industrial psychology field in the 1930s is a term used to describe a change in behavior that is due to an awareness of being observed [5]. The mechanisms that underpin this behavior change may in-

volve engendered beliefs about the researcher or observer which creates a desire to conform and to present oneself as socially desirable that subsequently leads to behavior change in line with perceived expectations [5]. The existence of the Hawthorne effect brought about by technological monitoring has been previously studied in research assessing clinical standards in healthcare populations [6,7] where it has been concluded that compliance with clinical standards increased due to these observer effects. If the Hawthorne effect has such an impact on individuals' behavior, it is logical to assume that the same mechanisms are present in sport when athletes are fitted with wearable technology. Ultimately, this technology affords detailed evaluation and scrutiny that may bring about the facilitation of performance.

Conversely, it is feasible that wearable technology may provide an obstacle to sports performance. Wearable technology is a relatively new introduction into the sporting domain, and as such the equipment employed may often appear restrictive to movement, heavy and unwieldy thereby negatively impacting performance. Additionally, there may be psychological disadvantages of wearing technology designed to evaluate and scrutinize performance. Indeed a psychological analysis of the users' employment of technology is critical as it allows the collection of information about the mental content of this conscious experience [8,9]. Having said that, gathering real-time evidence of such experiences presents a challenge with most scholars relying on retrospective methods such as interviews, observations, or questionnaires [8]. However, the presence of a microphone and audio recording capability on an eye tracking device, affords the opportunity to examine the user experience in real-time by collecting verbal output and overt self-talk data. Evidence of verbal output and overt self-talk from elite athletes may discern the perceptions of the wearer to the apparatus, the way in which the athletes cope with the experience of wearing the technology, and any potential impact it may have on their performance.

Self-talk is a psychological skill that has received increased attention in sport psychology research in recent years [10]. Self-talk is defined as a "dialogue [through which] the individual interprets feelings and perceptions, regulates and changes evaluations and convictions, and gives him/herself instructions and reinforcement" [11, p. 355]. This popular psychological skill can be used both overtly (externally) or covertly (internally) for both motivational and instructional purposes. Indeed, research suggests that motor skills requiring skill, timing, and accuracy are enhanced to a greater extent by the use of instructional self-talk [12], although the role of self-talk in situations characterised by uncertainty (e.g., where new technology may be employed) is unclear. Furthermore, relevant insight into athlete experiences of using wearable technology may be gained by gathering data on verbal reports and overt self-talk during its use.

Previous research has however explored the affective experience of human-technology interaction by analyzing it through the emotional model of competence and frustration [13]. This study reported the user experience of technology to be determined by a number of coping traits including pre-task self-confidence, technological problem-solving tendencies, frustration tendencies and task performance. Since competence is a central factor to successful performance, its assessment under conditions of wearable technology is valuable. If the technology is employed to measure performance and ultimately enhance it, then the effects of the apparatus must be examined for an understanding of how and why competency can be mitigated. Among basic needs for psychological growth and well-being, competency is an integral component for achieving satisfaction of these needs [14]. Without competency, one can engage in compensatory behavior, such as avoidance, often leading to a maladaptive cycle.

Focusing on this competency need, a self-handicapping / self-regulatory cycle has been proposed [15] where self-handicapping serves as a defensive strategy when the individual is faced with doubt, for example, when using a new piece of equipment, or perhaps being subject to evaluation by data captured from wearable technology. Self-handicapping is a cognitive strategy that serves to preserve one's self-esteem by managing the impressions of others in pre-empting performance failure. Self-handicaps are obstacles and barriers that are either claimed verbally (e.g., creating obstacles to success such as self-reporting stress levels or the high likelihood of failure of a task) or that manifest behaviorally (e.g., withdrawing effort such as avoiding practice sessions) in order to maintain perceived competence. Self-handicapping occurs when success appears accidental (non-contingent on performance), the individual will externalize the probability of failure to protect a fragile and limited confidence [16]. Coincidentally, externalizing failure allows for the opportunity to internalize any success as the ability to achieve in the face of external obstacles. This cycle is reinforced thereby evolving into a self-regulatory cycle with the potential to habituate [17].

As self-handicapping is a strategy that is ultimately focused on managing the impressions of others, this cognitive strategy may automatically be employed by individuals when faced with unfamiliar circumstances such as wearing new technology designed specifically to evaluate performance. However, the existence of this cognitive strategy or the exact circumstances of its use have not previously been identified in such scenarios. Furthermore, the wider concept of self-presentation and how it may be impacted by the use of wearable technology in these settings requires further investigation and discussion as the relationship between the two is currently unclear.

Since the development and use of wearable technology in sport is growing exponentially, it is critical that the impact

of such technology on the end users be fully understood. The purpose of this paper is exploratory: to examine the overt self-talk and verbal outputs of professional baseball players wearing eye tracking technology during practice conditions.

2. Method

2.1. Participants

A sample of 57 contracted professional baseball players from a Major League Baseball team in the United States of America (U.S.A.) participated in the present study during a pre-season spring training camp. Some (n = 12) were repeat major league competitors, either with the present team or another from the previous season. Other participants (n = 45) were from the team's minor league system, competing for a position with the major league team in the 2014 season. The classification of major and minor leaguers is fluid and a player's identity can change often during their career and even during a single season. These participants were all attending spring training, and as such, no one was yet on the major league roster; their level of classification as major or minor leaguers was to be determined on completion of the training camp. The participants were all male and ranged in age from 24 to 48 years old (M = 32 years, SD = 3.4).

2.2. Apparatus and Stimuli

The visual tracking and verbal data was captured by Applied Sciences Laboratory (ASL) mobile eye technology ("eye tracking device"). Participants wore the eye tracking device during live batting practice on-field and in bullpen sessions. Batters swung at pitches during the live practice however, during the bullpen sessions batters took position in the batter's box and allowed themselves to become a frame of reference for the pitchers to throw to. There was no attempt to swing at pitches by the batters during the bullpen sessions. All pitches were thrown from regulation distance of 60 feet 6 inches (18.44 metres). The eye tracker was used in the present study to collect scene camera (environmental) and audio data (via a microphone on the device) for subsequent analysis.

2.3. Procedure

The study was conducted in accordance with East Carolina University's Institutional Review Board ethical guidelines. After providing informed consent to participate in the study, the individuals were met by the researcher in an office beside the practice field on a one-to-one basis. The researcher explained that they were participating in an assessment of the visual-motor behavior and visual responses that batters elicit when attempting to hit a pitch. In addition, the researcher drew attention to the microphone feature on the eye tracking devices and explained that any verbal output would be recorded. The participants were informed that the data gathered from each individual would be shared both with the team coaching staff, and anonymously with the academic community. Each participant was then fitted

with the eye tracker which was calibrated to ensure the data collected was accurate. They then walked to the field and took a limited amount of swings (8 – 10) in response to pitches. In some cases, the participant was involved in bullpen sessions where they were merely a point of reference for the pitchers to throw to. During these sessions the participants may have employed imagery to rehearse their swing, footwork and hip rotation for example, however no actual attempts to swing at pitches were made. For some participants, there was a delay of several minutes between being fitted with the eye tracker and entering the batting box. After their stint in the batting cage finished, participants left the field and returned to the office where the eye tracking equipment was removed and the participants debriefed. The visual tracking, video and audio data obtained from the eye tracking device covered the equipment fitting phase, to the batting practice, to the return of the equipment to the researcher. The audio and video data gathered from each participant was downloaded into mp4 format for transcription. The audio data captured were results of unstructured dialogue between the participants and the experimenter, coaches, and teammates, plus any overt self-talk recorded during the process. The video data provided environmental context in the present study. It was this unstructured verbiage that was analysed for this research.

2.4. Data Analysis

The video and audio recordings were transcribed verbatim for each participant, which included overt self-talk and dialogues between the participant, their team mates and their coaches. Contextual data was also included in the transcriptions to detail the timing of the participants' batting in relation to their verbal output and their movement from interacting with the researcher in the office, to the batting cage and back. The data were subject to inductive thematic analysis, which involves a recursive process characterized by six distinct phases [18]: 1) familiarization with the data, 2) generating initial codes, 3) searching for themes, 4) reviewing themes, 5) defining and naming themes and 6) producing the results. The 57 separate transcribed verbal outputs were independently absorbed by the first, second and third authors to gain an in-depth understanding of the data [19]. Each researcher worked inductively through the data generating codes manually by writing notes on the transcriptions. These codes were identified features of the data that appeared to be of interest to the researchers given the research question. This process of latent analysis involved identifying and extracting consistencies from the transcribed text that adequately reflected the participants' experiences firstly on a case-by-case basis and subsequently across cases [20]. The codes generated were then sorted into overarching themes independently by the first and second authors who used mind mapping to help organise this process. The first, second and third authors then reviewed the proposed themes to ensure that there were identifiable distinctions between them and to ensure they presented an accurate representation of the data set. The themes were further refined and named to provide structure to the analysis before the results were produced which was designed to tell

the story of the data using illustrative examples throughout. This thematic analysis at the latent level allowed the exploration of the underpinning assumptions, ideas and conceptualisations driving the semantic content of the data [18].

2.5. Trustworthiness

Measures to enhance trustworthiness of the data included peer debriefing between the first, second and third authors at every stage of the data analysis in order to protect against researcher bias [21]. Additionally, the first and second authors engaged in coding consistency checks where validity was established when the same conclusions were drawn from the data. Additionally, peer debriefing was employed with the third author, playing a protagonist role, at each stage of the study to protect against researcher bias [21].

3. Results and Discussion

The aim of the present study was to undertake an exploratory examination of the experiences of the professional baseball players using the eye tracking devices during batting practice. The themes that emerged from the inductive analysis are presented in chronological order of the events that underpinned the athletes' experiences of the eye tracking devices: 1) "Before", referring to the period before batting practice or bullpen sessions commence where the athletes interact with the researcher and get fitted and acquainted with the eye tracking device; 2) "During", where the individual is in the batting cage, practising whilst wearing the eye tracking device, and 3) "After", where the athlete returns the device to the researcher. A summary of the findings is detailed in Figure 1.
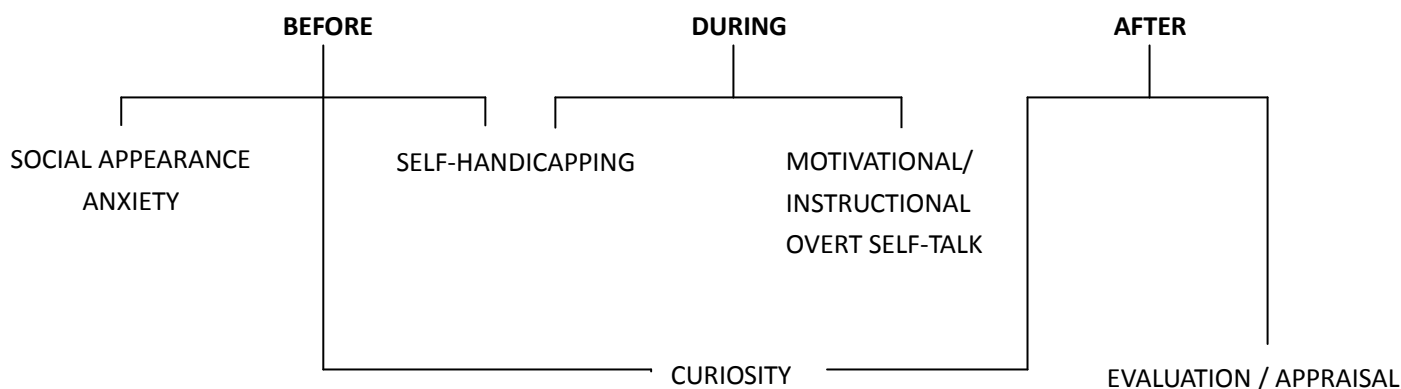

Figure 1. A summary of themes arising

3.1. "Before"

The participant's dialogue with the researcher during the fitting of the equipment and receipt of instructions regarding the study was characterized by three themes: social appearance anxiety, curiosity and claimed self-handicapping. The social appearance anxiety theme was driven by the participants' accounts of their perceptions of how they looked wearing the eye tracking technology. This included the verbal outputs of five players who remarked explicitly about their self-image, beyond merely "feeling weird." In a self-perception as an extension of the technology, Participant 35 claimed he was "el robo (the robot)" while participant 19 called himself "Robocop." Participant 40 said he had "the Halloween look." But, both participant 15 and 48 were more self-conscious about their perception of their "strange" appearance, each requesting to their peers: "don't make fun of me." There were numerous examples of attempts to deflect the social appearance anxiety using humor and self-deprecation. Some common comments included: "It's all science boys, don't worry" (Participant 4), "I look like a f****** stud" (Participant 51), "Robo cop coming through!" (Participant 9), "I'm all geeked up right now" (Participant 37)

and "Check this out dude...check me out...like Star Wars!" (Participant 11). Social appearance anxiety relates to concerns of how one's overall appearance may be evaluated [22]. In this cohort of professional athletes, social appearance anxiety may relate specifically to the fear of negative evaluation of the athleticism of the eye tracker wearer [23]. The impact of social appearance anxiety driven by the use of wearable technology on the performance of sport skills has not, to date, received any research attention. However, given the increasing use of wearable technology in the sporting domain, the relationship between these two variables warrants further investigation.

The second emergent theme, curiosity, was evident from the verbal outputs of participants who appeared to be naturally inquisitive about the function of the eye tracker. When fitted with the equipment, the participants expressed similar wonder about wearing the apparatus regardless whether they were headed to the batting cage or the bullpen. For example, during his fitting in advance of a bullpen session, Participant 21 stated that he had seen his teammates wearing the eye tracker and "I was wondering what they're doing." He then internalized his curiosity from his peers to himself: "I won-

dered what it looked like when you're wearing it". Once he set out on his walk to the bullpen, he became compliant: "Alright here we go…ready to roll". Similarly, Participant 22, after his fitting, sighed and exclaimed: "I wonder what this is all about then". Both of these players were compliant with wearing the eye tracker yet unsure of what lay ahead during their practice session, even though both were fully aware that the bullpen trials did not require any hitting or performance scrutiny.

The batting cage session however did involve an evaluative component: putting the bat onto the pitched baseball. Again the participants using the eye tracker during batting practice verbalized similar curiosity during their fitting before going to bat, yet their verbal outputs also suggested concerns about fairness and apprehension in the execution of their task. While all the batting practice participants were compliant during the fitting, some players did ask for adjustments while others were comfortable with the initial fitting. None of the participants complained about having to wear the eye tracker. This conformity may be due to their perception that this wearing of the technology was not voluntary but rather dictated by team management. The enquiry into fairness and equality originated from comments such as those by participant 5 who sounded concerned about being singled out for the eye tracking fitting. He asked: "It's about universal for our group, right?" This concern was mirrored by participant 16 who asked for a reminder as to how the data was going to be used: "what are you doing with the data?" and "are you doing this for everyone?" Across 13 participants there was a consistent apprehension about wearing the technology during batting practice marked by their perception that wearing the eye tracker was "weird." After fitting, the participants' overt self-talk involved words such as "weird" and claims of "this is going to be weird" or "this feels weird." As they set out for the practice setting, the players did so not in normal routine but unsure of what to expect on the field. "Here we go…" said participant 3 cautiously as he descended the stairs to the baseball field, "I hope I come out of this the other side".

Although the existence of curiosity in an environment where a novel product, designed to evaluate performance, is introduced is unsurprising, its presence is noteworthy. For example, this overarching theme may be linked to previous research by into worker curiosity [24]. Indeed, there is relevance in these findings given that the professional baseball players are, in fact, career employees. Curiosity is conceptually linked in the work context and is an important variable for the prediction and explanation of work-related behavior [24]. Certainly, curiosity, defined as a hunger for exploration, or a "thirst for knowledge" [25, p. 153], is considered predictive of success in professional performance [26]. These findings were mirrored by research into the development of Canadian coaches of Olympic medal-winning athletes [27]. They found that curiosity amongst this cohort was a reflection of the desire for continuous improvement in order to enhance their effectiveness in their work. Additionally, the presence of curiosity in such situations may be indicative of intrinsic motivation in sport [28].

The final theme that emerged in the 'before' period was claimed self-handicapping. Anticipating that their batting performance was going to be affected by the wearing of the eye trackers, the participants were heard saying to the researcher: "This is going to be weird" (Participant 16), and "I can't see with s**t, I can't see with regular sunglasses let alone whatever this is" (Participant 28). Claimed self-handicapping is a cognitive strategy that might involve suggesting that one is suffering from an injury or illness, or externalising reasons for perceived failure. Self-handicapping was initially believed to perform a role in personal self-esteem maintenance [16], however, it is now considered to serve an impression management (or self-presentation) function [29]. Indeed, research has revealed significant correlations between impression management concerns and self-handicapping tendency in athletes [30]. Additionally, it is suggested that environments emphasising competition and other-referenced standards may increase the likelihood of self-handicapping, thereby protecting the individual from the negative self-presentational implications of failure in a competitive climate [31,32]. Furthermore, a relationship has previously been discovered between self-presentation concerns and self-handicapping which they posited may be related to worries over making mistakes [23].

3.2. "During"

It was at the trial session ("during" phase) that the verbal behavior of the participants diverged according to the practice context. Those participants who engaged in the batting cage activity were much more verbal and expressive in overt self-talk and dialogue with others. The participants that went into the bullpen sessions did not engage in overt self-talk and exhibited little dialogue. The lack of verbal output in this context may have been indicative of the practice context: without having to hit the ball, the participants in the bullpen only had to stand in the batter's box and provide a frame of reference for the pitcher, while wearing the eye tracking devices.

Unlike in the bullpen, there was more overt self-talk during batting practice. In this context, two themes accounted for the reactions of participants to the eye tracking equipment during their batting practice: claimed self-handicapping and motivational and instructional overt self-talk. In continuation of the discussion above concerning claimed self-handicapping, the persistent use of this cognitive strategy was evident when the participants entered the batting cage to practice with the eye tracking equipment. Participants were heard saying to coaches and their peers "I don't even know what I'm looking at right now" (Participant 32), "This kind of impedes" (Participant 18) and "I feel like it's [the eye tracking equipment is] going to rip off my back" (Participant 41). The additional significance of the use of claimed self-handicapping during the execution of the batting practice was that these comments were aimed at an audience - ultimately the individuals that would evaluate their performance. This occurrence fits with the belief that handicapping tendencies are stronger under public than un-

der private conditions [p. 26, 33]. Moreover, the use of this strategy during batting practice may be useful in reducing negative emotional responses associated with anticipated failure, because it weakens the causal link between person and failure, meaning that the task or situation is perceived as less threatening [34,35].

The final emergent theme during batting practice was motivational and instructional overt self-talk. There were a number of instances of participants employing this verbal self-regulation strategy during batting practice including "...sit ball sit" (Participant 3) and "good one...yeah good one" (Participant 52). Self-talk has been described as "the key to cognitive control" [36] with the use of motivational and instructional overt self-talk serving a further self-presentation function. It has been previously posited that athletes viewed using positive (overt) self-talk were perceived as being better players than those using negative or neutral self-talk [37].

3.3. "After"

After the trials in the batting cage and bullpen, the verbal behaviors appear to converge along the two themes that emerge in this final sequence: curiosity and evaluation/appraisal. In particular, participants' curiosity of the eye tracker equipment bridges the before and after batting practice segments.

Of the two participants (numbers 21 and 22) who engaged in dialogue during the bullpen session, participant 22 exhibited the most post-trial verbal behavior. This individual's conversation with the researcher while the eye tracker was being removed was the most detailed inquiry of any of the participants, regardless of practice context. His curiosity was specific and impersonal: "Have you had any results that you can hypothesize or anything yet?" This curiosity lacking personal involvement could be reflective of the non-performance context of his bullpen session. Furthering this objectifying perspective, the self-evaluation and appraisal becomes less relevant to the bullpen experience, at least for a batter.

However, with the wearing of the technology, this appraisal becomes focused on the participant's visual behavior. Consequently, participant 22 remarks that the visual information of the wearable shows: "what you're looking at and how consistent your routine is...cool!" His interest in the technology is less one of the apparatus's effects on immediate performance but rather curiosity in the eye tracker's potential to enhance overall performance.

Within the batting cage trials, many of the participants exhibited curiosity directly related to their immediate performance. Participants 11 and 14 expressed interest in "seeing" what they did while hitting. They asked directly: "let me know how I did." Participant 4 was curious as to whether the data was saved in the system already. Participant 31 who wanted to know of his performance echoed this interest in the research: "Can you tell me a bit more about the study?" Participant 28 asked to see the eye tracker video of his batting practice.

Overall, and although curiosity was sustained from start to finish, it did appear to ebb in the post-trial sequence. The enhanced curiosity at onset during the apparatus's fitting may be caused by uneasiness with and the novelty of the eye tracking equipment on the part of the participants involved. After exposure to wearing the technology in the batting cage, the residual curiosity is centered on the uncertainty of the outcome. Thus, the request for feedback and the expressions of "interest" moves from the pre-performance curiosity of what's going to happen to the post-performance thoughts of what has happened.

The evaluation/appraisal in the post-performance phase was again dominated by expressions of "weird" utterances. The occurrence of "weird" as a reaction in this phase of the study was the most frequent (16) uttered by the participants. Many of these "weird" reports were extended to the inability of the players to adapt to the wearable while trying to hit the ball in the batting cage. Participant 15 said it was "weird" batting, and "the first couple of times I felt like I couldn't even see the ball." Participants 14 and 30 both remarked it was "weird at first," but especially the "depth (perception)." Participant 14 added that it took him time to figure "what I'm looking at." Some other reports alluded to this initial struggle to acclimate to the wearable; Participants 12, 23, and 31 specifically stated "it took a couple (of pitches) to see the ball." Participant 23 was more demonstrative: "It takes a couple to get used to. It's crazy technology!"

While the experience was termed "different" by participants 11 and 12, a few players expressed completely negative appraisals of the batting session with the wearables. Participant 42 exclaimed: "It was awful! I looked right at the thing [ball]. I just feel really awkward." The most negative reaction came from Participant 29, who was very pessimistic about his performance and its impact on his playing opportunities: "I'm fired…there goes my check for the year!" It is this remark that brings into focus the professional aspect of these participants' identity and what career implications have to be understood when examining their overt self-talk.

4. Conclusion

Thus, there are a number of important considerations to be applied to the results of this exploratory study. Firstly, the potential effect of this professional population on the findings is worthy of acknowledgment. As career baseball players, wearing visual assessing equipment is viewed as a team management decision and thus, an employee mandated activity. The pressure to perform, albeit in a practice setting, is fully internalised and may vary depending on the level of the athlete's experience, or indeed team selection status. The manner in which the data collected is shared with the coaching staff should be made clear at the outset of any activity involving wearable technology. As one athlete remarked to a teammate: "There goes my pay check for the

year." Assessing wearable technology on the user may be population-specific and requires more study on various sport groups both professional and amateur, across cultures and gender.

Secondly, under game conditions, wearable technology has not been examined for its effects on the user, since the utilization of such technology in an unobtrusive manner has yet to be perfected. The research on wearable technology in sports is limited to practice sessions and less competitive settings. Whether this has less of a stress or anticipatory anxiety effect on the wearer also requires further inquiry. Without this further examination, the conditions resulting from wearing technology while engaged in competition cannot be fully understood.

Lastly, more rigorous baseline studies must be engaged in order to clarify more precisely what cognitive and motor reactions are occurring while wearing monitoring equipment. The most effective starting point for further study would be the design and implementation of a repeated measures study where athletes' performance is recorded while wearing technology, and then subsequently without. This will allow a more effective quantification of the effects of wearable technology on athletes' performance. In addition to this, future research should further investigate the presence of viable placebo effects and the potential for the Hawthorne effect (Franke & Kaul, 1978) to influence performance while being remotely assessed through wearable technology.

These and other questions arise because of the lack of research in the area of wearable technology. However, technology will continue to have a rapidly expanding role in sports, whether as wearable assessment tools or objective remote data collection equipment. The research must keep pace with these advances in order to properly critique technologies use on athletes and create meaning on the data these tools render.

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