Abstract—Computer graphics research has long prioritized image quality over frame rate. Yet demand for an alternative is growing, with many esports players turning off visual effects to improve frame rates. Is it time for graphics researchers to reconsider their goals? A workshop at the 2023 SIGGRAPH Conference explored this question. Three researchers made provocative presentations, each of which were then discussed by dozens of research and industry attendees. We summarize those presentations and discussions here, concluding with potential research questions, and future plans for esports at SIGGRAPH.

At the SIGGRAPH 2023 Conference, the workshop “Less is More: Rendering for Esports” [1] was held in the Conference’s Frontiers venue, advocating a reconsideration of the goals for computer graphics research. A large part of the field’s effort has been directed toward realizing photorealism: visuals that seem “real”. Yet nearly 20 years ago, “father of digital cinema” George Lucas stated [2] that “the real leap has been made;” graphics researchers are now only working on “better knobs and whistles.” And today, many esports players reduce rendering quality [3] in the effort to win. Given that game industry revenue is now several times larger than movie revenue [4], a reconsideration of the research goals for computer graphics seems timely.

The half-day workshop consisted of an introduction by Watson; three 10-minute, provocative presentations each followed by 50 minutes of participant discussion; and a short conclusion by Kim. Spjut’s presentation began things with a bang, titled “Image Quality Doesn’t Matter”. Lee’s presentation, titled “Why Would Gamers Use Low-Graphics?”, described the potentially harmful visual impacts of photorealism studying in collaboration with Yoo. Shirley then rebutted many of Spjut’s claims with the presentation “Image Quality Matters”. Participants — including Raymond — wrote their reactions in parallel into a shared online document, and also discussed them interactively and in person. Nearly 40 attendees gave their emails to organizers, with dozens more participating. Most were from the game industry.

Below, we describe each of the three presentations, and summarize the participant reactions. We conclude by distilling the presentations and reactions into possible research goals.
revenue nearly $80 billion [10], while Major League Baseball was $10.3 billion [11]. Aside from its purely digital venue, esports distinguishes itself from traditional sports meaningfully by the lesser role of physical fatigue in training and competition; and by remote competition, with online gaming supporting high-level competition without travel to a shared location. Thus esports represents a new and growing domain for human competition and excellence that overcomes many geographical and socioeconomic limitations.

Image quality doesn’t matter
Spjut argued that image quality does not matter for esports games. He supported this with three claims. First, cinematic aesthetics do not matter because they often take significant computational power to produce, and can obscure active game elements (See Figure 2). Second, anti-aliasing and denoising are lossy and approximate. Third, gameplay is paramount for esports gamers; it keeps them coming back year after year. The attendees discussed these and more topics.

Frame rate
One theme of discussion was higher frame rates (and display refresh rates), with a number of attendees observing that esports gamers prefer high refresh rate displays over high resolution much of the time. For example, esports displays are still primarily 1080p (full HD) but with refresh rates ranging from 240-540 Hz. In contrast, nearly all televisions for average consumers are 4k, with the majority still at 60 Hz. While the bandwidth required for an 8k60Hz display is the same as a theoretical 1080p960Hz display, it seems most esports gamers would prefer the second. Other attendees noted that consoles still do not support high frame rates, and are the platform for most AAA (high-production value) games. Yet others noted that high frame rates are important for minimizing latency — an important aspect of player performance in many esports. In one sense, this esports market has diverged from Blinn’s law, a rule that suggests that rendering time will be a constant with computation added to fill the 16 ms budget [12]. In contrast, the “esports law” appears to be that the resolution and game will be constant, while frame rates will be as high as possible.

Game settings and player preference
Another point of discussion revolved around player preferences and the in-game settings options. Attendees pointed out that in Starcraft 2, pro players choose settings that are mostly “low” (few, less elaborate visual effects), but with a few higher choices, explicitly selected to minimize distractions irrelevant to performance [13]. It may be that competitive players choose settings to maximize “scene readability” instead of engaging image quality. Another related discussion focused on an individual’s choice of settings, which may change with time or mood. For example, one player might start a game, and choose to turn all the settings up to get the most cinematic visuals. Then later, that player may turn many settings down as he or she seeks maximum skill and performance.

Gameplay matters more
Attendees called for more gameplay research by computer graphics researchers. While graphics are about the visuals, there’s a relationship between visual presentation and the way players interact and engage with the gameplay. For example, stealth can be accom-
FIGURE 2. Cinematic game effects obscure game elements, and can be computationally expensive. Figures from PCGamer.

FIGURE 3. Battlebit Remastered, used with permission.

plished through rendering techniques (e.g., shadows, low contrast) or through gameplay (e.g., bushes in League of Legends, invisibility abilities), and research is needed on these various options and their impacts. Some games (like Roblox, Battlebit Remastered – Figure 3) explicitly focus only on gameplay while intentionally leaving graphics minimalistic.

Fairness
Some attendees sought competitive fairness by making the experience as equal as possible across users. While consoles are quite uniform, PCs have a wide variety of capabilities, and will end up with very different performance even if the settings are the same. Some machines will be incapable of supporting certain computer graphics techniques, compromising fairness for players using that hardware. While this problem is tough to solve without forcing players onto the same hardware (as at tournaments), attendees did have suggestions. For example, cosmetics or “skins” are regularly used to monetize esports, and can often have a significant impact on player performance. For fairness, games could enforce only the use of skins that create a balanced play experience, for example balancing saccadic latency [14]. Another attendee suggested that a global frame rate limit may also increase fairness on different hardware.

Competitive advantage of lower graphics
Finally, discussion revolved around why players might prefer lower graphics, and whether they actually provide an advantage. While frame rates are often higher and latencies lower at low graphics settings, the reduced visual complexity of the game may be advantageous on its own. Riot and other developers do art design and direction based on “low” graphics settings, ensuring that all players have a similar artistic feel from the game. Some attendees observed that games like Starcraft reduce distraction at low settings by minimizing unnecessary death animations. Fortunately the following presentation elaborated on this topic.

Why would gamers use low graphics?
Lee and Yoo began by noting that in fast-paced competitive video games, players must process visual information presented on the screen as quickly as possible and make appropriate decisions. Yet when higher visual effects are on and increase the detail visible in a scene, it can often become more difficult for players to recognize essential information — much like trying to find a paperclip on a cluttered desk. This can increase players’ reaction times and create persistent disadvantages in video games where victory can be decided by a split second. In contrast to most previous studies, this hypothesis suggests that graphics settings directly affect player performance, rather than indirectly by lowering frame rate.

They then described a pilot experiment that examined this hypothesis. The amount of visual clutter humans perceive in an image can be quantified using a method proposed by Rosenholtz & Nagano [15]. Using
this method, they estimated the average change in visual clutter in Valorant (a popular first-person shooter game) when high visual effects are turned on or off. Visual clutter was calculated by randomly extracting frames from video recordings of both standard online gameplay and local custom gameplay, with custom play involving solo play on a map without enemies. All game play was performed by Lee or Yoo, and the character they played was not changed during a game.

They found that turning on all visual effects increased average visual clutter by nearly 10% (see Figure 4). In general, as visual clutter increases, humans need tens of milliseconds more search and reaction time to locate targets [15]. Is this a significant difference? Considering how meaningful a difference in latency of a few tens of milliseconds is to serious gamers, the answer to this question is “probably yes.” Of course, this is only a pilot experiment, to draw more definitive conclusions, future studies should collect gameplay videos from more characters, more players, and more diverse game situations.

Lee and Yoo’s presentation at the workshop elicited lively discussion from attendees. Participants began by discussing the limitations of the pilot experiment, pointing out that a wider range of player expertise should be taken into account, and that the impact of visual clutter could be reduced through training. However, the discussion soon developed into two major themes: game design considering visual clutter, and the relationship between visual settings and fairness in competition.

Designing for visual clutter
Several participants pointed out that designing for visual clutter is not easy, and may not significantly affect player enjoyment and immersion. Some proposed that development environments provide designers with tools that estimate visual clutter. Others suggested limiting the number of visual settings options available to players, to reduce decision paralysis. Some argued that visual clutter is a normal element of gameplay, and that qualitative, formative player research on clutter should be conducted, to complement quantitative approaches. Similar practices for game audio settings exist (e.g., manipulation of footstep sounds).

Visual game settings and fairness
Several participants noted that allowing game settings to vary from player to player can reduce fairness, but interestingly can also increase game accessibility. For example, for games to be available in certain countries’ markets (e.g., China), blood cannot be red, which may affect player performance. Some participants suggested that players be informed of the potential impact of each visual setting on their performance. Others observed that simpler (less clutter) is not always better: ultimately, reducing visual clutter could remove essential visual elements, creating even more fairness concerns. For example, in the popular game PUBG, low graphics settings can remove grass, making it more difficult for players to hide. Interestingly, some participants said that in team-based games they feel bad if their teammates use unfavorable visual settings, which Lee and Yoo think may result in peer pressure to seek out better settings. Participants also compared differences in visual settings to differences between players’ input devices.
More study of low graphics
Participants agreed that visual settings are related not just to frame rate, but also can directly affect players' perceptual performance. However, whether the effect of visual settings is important enough to be considered in game design remains an open question, as it may conflict other design goals, like fun. Visual settings may also influence players' perceptual performance through other mechanisms (e.g. audio); research these through in-depth player interviews could prove fruitful.

Image quality matters
Shirley argued that while realistic graphics may not heavily influence player performance, achieving cinematic graphics image quality is vital for most player engagement. While esports is still young, it's reasonable to expect that a large player community for a given game makes it a better venue for esports. This is analogous to traditional sports: they have many professionals, but they have even more fans that view or play the sport. For example in golf, professionals are followed by many fans, who are at least partly attracted to the game by its beautiful setting (see Figure 5).

Achieving cinematic rendering at 60 FPS is challenging on most hardware. Historically, game designers have been able to rely on hardware improving rapidly, but a slowdown in Moore's Law has diminished such speedups. Moreover, many now play games on mobile devices, and it is hard to create AAA graphics with only 10 watts of battery power. Yet mobile players cannot be ignored: many international players compete on mobiles, and capturing such players is necessary to fully broaden the player base. This incentivizes using simpler, old-school graphics algorithms, which are not cinematic. Supporting engagement across such extreme platform variation is difficult, particularly given esports' need for fairness. Competitors with dissimilar platforms will require not only different visual experiences, but those visual differences cannot give one competitor an unfair advantage. Even if cloud gaming displaces mobile gaming, competition between players who have paid for different levels of cloud service will create similar challenges to delivering fair and simultaneously engaging experience.

Hardware vs. cloud, and fairness vs. experience
Several attendees emphasized that the visual and audio hardware used by players varies widely, which makes it difficult to maintain a level playing field (e.g., HDR versus LDR color, and high quality headphones versus external speakers). Participants noted that traditional sports often require uniform and limited equipment for professional competitions (e.g., Formula One racing), while amateur and informal competitions have few such constraints. Cheating is possibly the most important threat to fairness, which may in fact drive increasing use of cloud gaming, with thin game clients offering fewer cheating opportunities. Finally, participants observed that unlike traditional sports, in esports spectators and players can have different visual experiences (e.g., prioritizing engagement rather than performance).

An esports-inspired research agenda for computer graphics
The workshop's lively discussion suggests several possible new directions for computer graphics research. Many of these directions describe goals that are often
in tradeoff with one another, much like the well-known computer graphics tradeoff between frame rate and visual detail. Part of future research will be to understand not only how to achieve these goals, but also how reaching some of these goals impacts others:

- **Player performance.** For competitive gamers, winning is more important than entertainment — or perhaps, winning is entertainment. For such players, computer graphics should maximize interactive, in-game performance. Often, this means lowering latency and increasing frame rate, so that players see what is happening in the game more quickly and clearly. This reduces visual detail — which can itself improve performance. The correct tradeoff will likely vary genre-to-genre, game-to-game, and perhaps even player to player.

- **Engagement.** Like traditional sports, esports has more amateur than professional players, and an even larger audience. Their engagement is crucial to esports success, and depends significantly on the game's visual appeal. How can games support both high performance and engagement? This will be particularly challenging with the great variety of gaming platforms, particularly across growing international markets.

- **Gameplay.** Cinema engages not only visually but also narratively. Similarly, games engage not only with visuals, but also with gameplay. Computer graphics are the medium within which cinematic photorealism can be achieved, and decades of research sought this goal. Yet little computer graphics research has been directed toward achieving excellent gameplay.

- **Fairness.** In sports, great effort goes into ensuring that the best play wins: for example by giving players the same rules and equipment (or equipment constraints). In esports, the wide variety of gaming platforms and network connections makes achieving fairness difficult. Computer graphics might help with reductions to a graphical “lowest common denominator”, with more flexible graphics constraints that make visual settings changes part of competition, or with gameplay enhancements for disadvantaged players. The appropriate reductions, constraints and enhancements are open research questions.

- **Individual control.** Unlike movies, games are configurable, with players adjusting computer graphics settings to suit their own priorities: engagement and fun, performance and winning, or more. Indeed these changes may be made over months, or even within the same game. Yet finding the settings that best achieve such goals is extremely difficult for players, and research might strive to change this.

By progressing toward these new research goals, we hope that computer graphics will not only grow the gaming industry, but also the increasing range of other industries that rely on highly interactive visuals, including drone piloting, telesurgery, and virtual training.

We hope to build and maintain an esports- and game-oriented community of computer graphics researchers, which will progress in these directions. To stay connected to this community, please add your name to our email list at https://bit.ly/esportslist, in which you can request membership to our cg4esports discord. In it, we will be announcing future events at SIGGRAPH and other conferences.

### REFERENCES

https://gameranx.com/updates/id/416500/article/gaming-is-five-times-bigger-than-movies-now


Benjamin Watson is an Associate Professor of Computer Science Department at North Carolina State University, where he directs the multidisciplinary Visual Experience Lab. His work has long focused on temporal concerns in computer graphics rendering. He has organized several esports workshops, and chaired the ACM I3D and Graphics Interfaces conferences.

Joohwan Kim is a vision scientist and display engineer, and a Research Scientist at NVIDIA, where he published several papers on novel displays and experiments focused on esports and VR. His expertise includes evaluating visual display artifacts (e.g. flicker, judder, motion blur) and human experiments. He recently co-organized an esports workshop with Watson in Japan.

Josef Spjut is a Research Scientist at NVIDIA focusing on esports, where he helped realize NVIDIA’s low-latency Reflex displays. His love of esports led to his doctoral work on ray-tracing hardware. He was Games Focus Area Chair for SIGGRAPH 2023.

Byungjoo Lee is an Associate Professor of Computer Science at Yonsei University, where he directs the Yonsei Esports Lab. His work on esports interaction and input devices has won several ACM CHI Best Paper Honorable Mention awards.

Mijin Yoo is an undergraduate student in the Department of Electrical and Electronic Engineering at Yonsei University. She is currently conducting research in esports and Human-Computer Interaction (HCI) at the Yonsei Esports Lab.

Peter Shirley is Vice President of Graphics at Activision. Previously, he was Distinguished Research Engineer at NVIDIA, where he was key in realizing NVIDIA’s interactive ray tracing technology. He is co-author of the widely used Fundamentals of Computer Graphics textbook, and a member of the SIGGRAPH Academy.

Rulon Raymond is the Director of Engine Engineering at Infinity Ward (Activision). He has over 20 years of graphics engineering experience in the AAA gaming space, including a focus on performance, scalability, and the visual implications of fairness in a competitive setting.