Better be quiet about it! The Effects of Phantom Latency on Experienced First-Person Shooter Players

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ABSTRACT

Users' expectations about systems alter how they interact with them, thereby influencing their experience. Latency is also known to alter experience and performance in interactive systems, particularly in video games. Currently, it is unclear if users' expectations influence latency-based effects. We report the results of an experiment (N = 24) in which participants played a video game with four levels of phantom latency (30 ms, 60 ms, 90 ms, and 120 ms). Crucially, all rounds were played with 75 ms of actual latency, we merely changed its presentation in the game. We show that a high phantom latency reduces game experience and performance. Participants were least accurate and effective when playing with 120 ms while feeling the least competent and tensest. We concluded that the effects of latency are partly expectation-based. Latency researchers, developers, and gamers must be aware of the effects induced by the expectation of latency.

KEYWORDS

User expectation, Placebo, Nocebo, Video Games, Latency

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1 INTRODUCTION

In medicine, a placebo is a sham treatment or substance with no known therapeutic value or active ingredients respectively [4, 6, 29], which has a positive effect on a patient. For example, placebos can relieve pain [12, 41], support the treatment of physical conditions [28], and even aid the therapy of psychiatric disorders such as anxiety disorder [22]. The primary factor underlying the placebo effect is one's expectation of improvement. These expectations are formed by previous experience, contextual cues, and biological characteristics that ultimately determine the response to a placebo [22, 41]. On the other hand, the complement to a placebo is called nocebo, in which a sham treatment or procedure leads to a harmful response (e.g., blocking therapeutic effects of clinical drugs [13]).

The users' interaction with digital environments is also fundamentally shaped by their expectations about it. Thus, the interplay between humans and computer-based systems is potentially subject to the pla- and nocebo effect. Previous work showed, for example, that telling users that they interact with an intelligently adapting user interface increases their task completion rate compared to users testing the same system without said suggestion. Crucially, both user groups tested the same system without an intelligently adapting user interface [29]. In a subsequent study, the authors demonstrated that the placebo effect, induced by suggesting an adaptive interface, sustained even after the initial interaction [29]. Other work investigated how the prior expectation about a video game's rating influences the actual users' rating of the game [40]. Users with a higher primed expectancy about the game's rating rated the game significantly better compared to users with no or a lower primed expectancy. Similar research in this line of work showed that players of video games rated a tested game with higher game experience and achieved higher gaming performance if they believed they played in cooperation with an intelligent agent [14]. A considerable amount of evidence shows that expectancy-based effects fundamentally form the experience and performance in digital environments. However, one example of a concept crucially relevant to human-computer interaction and potentially susceptible to expectancy-based effects but yet not researched in that manner, is latency.

Latency, the time between a user's input and a system's output, is ubiquitous. No matter the device used, be it a touch-operated mobile device, a virtual reality (VR) headset, or a stationary computer, latency will always play a crucial role when interacting with computer systems [38]. The temporal offset between a user-generated input to a system and the system's corresponding output is inevitable - independently of the structural size of novel computer chips, how much bandwidth the latest fiber optic-based network connection provides, or how precise and responsive nowadays' interactive systems are. Latency influences user experience and performance for a wide range of task and interaction modalities

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such as virtual reality [1, 48], mobile devices [20, 21], classical workstations, and augmented reality [31, 42]. For instance, Jota et al. [26] and Annett et al. [3] showed that latency of more than 25 ms leads to reduced user performance when interacting with a mobile device. Although performance does not increase below a latency of 25 ms, Ng et al. [44] found that users perceive latency starting at 2 ms. Building on this, Ng et al. [43] showed in other work that users can detect discrepancies between 1 ms latency and 2 ms latency in some tasks. Video games are particularly affected by latency. Latency leads to players scoring fewer points [18], requiring more time to complete a game objective, failing to complete the objective at all [7, 11, 15], and a reduced gaming experience [2, 32, 33]. However, while a large body of work investigated the effects of latency in video games, less is known about the potential effects of latency perception and expectation. Investigating expectancy-based effects induced by suggested latency (phantom latency) is crucial for a range of reasons. First, researchers investigating latency may need to account for the effect of phantom latency when designing studies and briefing participants. Second, developers must know how to communicate latency to users without interfering with their performance and experience. Third, players must be aware of potential effects induced by the mere perception and expectation of a latency value (for example, in a game's user interface such as in *Counter-Strike: Global Offensive* [49] or *Fortnite* [17]). It is currently unknown how phantom latency and potentially induced expectancy-based effects manipulate game experience and performance in video games.

Previous work shows that sham treatments or procedures known as a placebo, which are based on the recipient's expectation [4, 6, 28], aid in treating physical [12, 28, 41] and psychological conditions [22]. On the other hand, expectations may also hinder a successful treatment, known as the nocebo effect [13]. Previous work also shows that users of digital environments are susceptible to effects induced by the users' expectations of it [14, 29, 40]. One factor fundamentally influencing the interaction in said environments is latency [3, 26, 38]. Latency particularly affects players of video games [7, 10, 15, 32, 33]. However, while a large body of work investigated the effects of latency in video games, it is currently unknown if video games are affected by placebo and nocebo effects induced by phantom latency. Our work closes this gap by providing in-depth insights on how phantom latency affects game experience and performance in a fast-paced first-person shooter video game. To achieve this, we developed a latency overlay for *Counter-Strike: Global Offensive* (CS:GO) - a popular video game in the e-sports scene. Using our overlay, we conducted a study while presenting experienced CS:GO players four levels of phantom latency (30 ms, 60 ms, 90 ms, and 120 ms) while playing the game. Each participant played with all levels of phantom latency. Crucially, all rounds were played with an actual latency of 75 ms. Our analysis shows that phantom latency significantly alters game experience and performance. Players were significantly less accurate, dealt less damage per hit, and had a significantly lower feeling of competence when playing with 120 ms of phantom latency compared to playing with 30 ms. Holistically considering all gathered data, we demonstrate that researchers investigating latency need to account for expectancy-based effects induced by a study or the researchers themselves. Furthermore, we show that the mere perception of latency influences players' performance and experience. Video game players and developers should be aware of the bidirectional effects induced by phantom latency and its' perception.

2 RELATED WORK

Placebo and nocebo effects are well researched within medicine and psychology [6, 28]. Furthermore, expectancy-based effects also alter user interaction with digital environments. This section first provides an overview of how user expectation influences interaction and continues to shed light on another crucial factor influencing user experience and performance in interactive systems - latency. Next, we showcase that one type of digital environment particularly negatively affected by latency are video games. We briefly elaborate on *Counter-Strike:Global Offensive*, a fast-paced first-person shooter highly popular in e-sports and relevant for video game research. Finally, we conclude this section with a summary, showing why it is necessary to account for placebo, respectively a nocebo, effect when investigating latency and its effects in video games.

2.1 The Effects of User Expectations in Digital Environments

Users' expectations of a system manipulate their experience and performance when interacting with it. For example, Rutten and Geerts [46] found that the perceived novelty of a system influences the attractiveness and joy of using the system. Participants who were told that they would test a novel system rated the system with a higher level of attractiveness and joy of use than participants who were not primed on the system's novelty. In similar work, Denisova and Cairns [14] demonstrated that the pre-experiment description of a game given to the participants influences the level of perceived immersion while playing. In their work, the authors compared two groups of participants, with one group primed on sham advanced game features while the other group did not receive a pre-experiment description. In a subsequent analysis, the authors found that the group which received a pre-experiment description rated the game with a higher level of immersion. Jenkins et al. [25] and Michalco et al. [40] explored how knowledge about a game's rating modulates the rating of the game in a study. In general, if participants were told that the game was rated with a high score (e.g., 90 %) it was more likely that they also rated the game with a higher score. Vice versa, if the participants were told the game was previously rated with a lower score (e.g., 60 %), the game was rated significantly lower. In the same line of work, Livingston, Nacke, and Mandryk [35] showed that professional reviews and user comments on a game affect the individual game experiences of players. The authors found that negative comments have a particularly adverse effect on the players' experience.

While previous work shows that a user's expectation about an interactive system modulates the evaluation of the system and the interaction with it, it does not aid in answering the question of if the adverse effects of latency in said systems are (partly) expectation-based.

2.2 Latency in Digital Environments and Video Games

The analysis of latency and its' effects on digital environments has a long tradition in human-computer interaction research. Already in 1981, Card [8] described how a temporal offset between in- and output negatively influences the interaction between humans and computers. Card shows that users interact with interactive systems in a continuous feedback loop; The users initiate an interaction by entering data into the target system, for example, by clicking on buttons in a user interface. The system receives and processes the input and reacts to it with an output. The user, in turn, can now react to this loop and potentially starts another loop cycle. Latency in interaction reduces the loop throughput capacity and, thus, increases the time required to complete a task.

Recent work showed that latency leads to diminished user performance and experience in a wide range of tasks and interaction schemata: Jota et al. [26], for example, demonstrated that a latency above 25 ms leads to a decreased user performance in direct touch-based tasks. Schwind et al. [48] show that latency reduces the feeling of immersion in full-body motion-captured virtual reality (VR). Kaaresoja et al. [27] showed that users evaluated a touch keyboard with a minor feedback latency as more pleasant to use than keyboards with higher latency. While previous work shows different thresholds of at which level starts to affect user performance and experience negatively, NG et al. [43] showcased in a *Just Noticeable Difference* study that users can differentiate between 1 ms and 2 ms of latency in specific tasks.

Video games and their players are also negatively affected by latency. Previous work by Claypool and Claypool [10] showed that different game genres are differently affected by latency. The authors found that fast-paced games which require split-second decision-making and action feedback, such as first-person shooter games, are predominantly negatively affected by latency. Other works investigating video game latency utilize latency to predict the player's performance in the game [36]. The adverse effects of latency in video games manifest in different forms: Players score fewer points [18], require more time to complete a game objective, or fail to complete the objective at all [7, 11, 15]. Recent work also showed that latency significantly reduces gaming experience [2, 32, 33].

In summary, while existing work shows that latency affects user experience and performance in various tasks, especially in video games, it does not show whether user expectation of latency is a shaping factor influencing its actual effect.

2.3 Counter-Strike: Global Offensive

Counter-Strike: Global Offensive is a team-based, fast-paced first-person shooter (FPS) game published by Valve in 2012. Despite its age, CS:GO is still played daily by about 900.000 unique players [50]. In CS:GO, two teams of five players contest against each other. One team takes on the position of the so-called *terrorists*, while the other team is called *counter-terrorists*. The terrorists win a round by either planting a bomb and using it to detonate a game objective or taking out all the counter-terrorists. The goal of the counter-terrorists is to prevent the terrorists from planting the bomb by either guarding the game objectives or eliminating the opposing team. Despite this seemingly simple premise, CS:GO is exceptionally challenging and tactical, requiring extensive knowledge of the game world, game mechanics, and when to use which strategy to achieve the objective. As a result, CS:GO is the subject of research in numerous publication [32, 33, 37, 39, 51].

2.4 Summary

Previous work showed that users' expectations of a system fundamentally alter their experience [14, 25, 29, 35, 40, 46]. Similarly, showing information about a system, such as the current latency, also possibly shapes the user's expectations. In general, interactive systems [26, 27, 43, 48], and video games in particular [7, 11, 15, 18, 19], are negatively affected by latency. Starting at 25 ms players score fewer points, are less accurate, or cannot complete a given game objective. While it is evident that latency negatively affects game experience and performance, it is unclear if there is an expectation-based component to the effects of latency in video games. In particular, it is unknown if the expectation of latency, induced either by a sham latency (phantom latency) display or by the study design, alters the game experience and performance of video game players.

3 INVESTIGATING THE EFFECTS OF PHANTOM LATENCY IN VIDEO GAMES

To investigate how phantom latency affects game experience and performance in video games, we conducted a study with high-skilled participants playing CS:GO. We used CS:GO since fast-paced video games have already been shown to be notably affected by the adverse effects of latency [10, 32, 33]. Therefore, we modified the game with a self-developed overlay that can indicate any latency value.

3.1 Apparatus

We used CS:GO's free-for-all (FFA) game mode. In FFA, all players compete against each other without forming teams. In line with previous work, all gaming rounds were played on *Mirage* (the most played map in CS:GO) using the *AK-47* (the most used weapon in CS:GO) [32, 33]. We prevented players from switching or obtaining other weapons via the in-game console. Furthermore, to prevent confounding variables from playing against other human players, we conducted the study using CS:GO's built-in bots (hard difficulty).

We developed a custom overlay for CS:GO using *Java* to display phantom latency to the participants. Since latency in the wild is composed of numerous factors, it never is perfectly constant. Thus, we added random variation to the displayed phantom latency. When using the overlay, the displayed phantom latency randomly varies within a range of 3 ms; i.e., if set to a latency of 30 ms, the overlay displays a phantom latency between 27 ms and 33 ms. The displayed value is updated every 400 ms within that range to establish a more natural latency behavior. Figure 1 depicts a screenshot of an unmodified CS:GO version (left) and a screenshot of CS:GO while using our developed latency overlay (right).

The game was executed at a fixed 144 frames per second (fps) on a stationary high-end workstation with an Intel i9-11900K, an Nvidia GeForce GTX 3080, 32 GB RAM, and an M.2 SSD. In addition, the workstation was connected to a HyperX Cloud II headset, a

Corsair K100 keyboard, a Logitech G502 HERO gaming mouse, and an MSI Optix 27" monitor. We measured the latency of our system running CS:GO using the game's internal server architecture, which allows to manipulate and control the latency of gaming sessions.

3.2 Study Design

We designed a within-subjects study and utilized the independent variable (IV) PHANTOM LATENCY which is factorized on four levels: (1) *30 ms*, (2) *60 ms*, (3) *90 ms* and (4) *120 ms*. The levels of PHANTOM LATENCY were designed in accordance with related work, which showed different latency thresholds before impacting game experience and performance [7, 10, 11]. Liu et al. [33], for example, investigated negative effects of latency in a range from 25 ms latency up to 125 ms latency. Further, we excluded a *0 ms* level for PHANTOM LATENCY, because latency in the wild is never zero. Each participant played with each level of PHANTOM LATENCY. Crucially, we controlled the true latency in all conditions to remain at 75 ms. The rationale to set the true latency to 75 ms was two-fold: (1) It was crucial to conceal the fact that latency over conditions did not change. Hence, we required a baseline that induced negative latency effects but was neither notably too low nor too high since all participants were highly familiar with CS:GO and how latency affects the game. Secondly, (2) we did not use one of the tested levels of phantom latency (30 ms, 60 ms, 90 ms, and 120 ms) as a baseline to prevent a match and possibly interaction between the displayed level of phantom latency and the true latency. All conditions were balanced using a Latin Square to prevent sequence effects.

We recorded a range of dependent variables (DV) to measure the participants' game experience and performance. We used the 33-item *Game Experience Questionnaire* (GEQ) [23] with its seven subscales *Sensory*, *Flow*, *Competence*, *Positive Affect*, *Negative Affect*, *Tension* and *Challenge* to quantitatively evaluate game experience and coupled it with qualitative questions focused on the participants experience with latency in the past gaming round and the participants' perception of latency.

We operationalized the players' performance in different variables: (1) *Score* - the overall amount of points achieved for hitting and eliminating adversary bots, (2) *Kills* - numbers of enemies eliminated, (3) *KD-Ratio* - the ratio of enemy kills and in-game deaths. A higher *KD-Ratio* indicates a more efficient and effective gaming session, and vice versa, a lower *KD-Ratio* correlates to worse performance. (4) *Number of Headshots* (*NoH*) - number of headshots dealt. A headshot in CS:GO deals maximum damage and instantly eliminates the hit bot. However, they are excitingly hard to hit; the further the target is away and the more the target moves. Reliably hitting headshots is a crucial skill for every CS:GO, player. Lastly, we used (5) *Damage Per Hit* (*DpH*) as additional DV. Besides headshots, CS:GO also implements different hit zones on the player characters. For example, shooting an enemy in the foot does less damage than shooting an enemy in the chest. Performing effectively in CS:GO requires players to deal the highest amount of damage with the lowest possible hits.

3.3 Procedure and Task

Participants were greeted at the laboratory by the experimenter. After briefing them about the general procedure of the study, they gave informed consent. Participants were told that they would test a novel latency representation in CS:GO (our latency overlay). They were, however, blind to the study's exact purpose (testing the effects of phantom latency on game experience and performance). After the introductory briefing, participants were asked to fill out a demographic questionnaire, answering questions about their age, gender, handedness, experience in FPS games, hours played in CS:GO, their CS:GO rank, what they consider to be high latency, and how they usually deal with high latency while gaming. Next, participants were led into a separate room where the gaming setup was situated. CS:GO was already executed in full-screen mode on the stationary workstation. The participants were seated in front of the workstation and started the gaming sessions with a 10-minute warm-up round in CS:GO's FFA. A warm-up was conducted to allow the participants to familiarize themselves with the gaming setup and the FFA mode. After the warm-up, participants had a two-minute break before the first gaming round with PHANTOM LATENCY started. Each round lasted 10 minutes. Participants were asked to answer the GEQ after each round. After answering the GEQ, participants were asked if they felt latency in the last round and, if so, how they felt it manifested in the game. Next, participants had another 2-minute break before starting the subsequent round.

3.4 Participants

Previous work showed that the effects of latency on game experience and performance could reliably be detected with a comparatively small number of participants [32, 33, 36, 38]. In line with this work, we also recruited 24 participants (21 male, 3 female) through our institution's mailing list. The participants' age ranged from 18 years to 42 years, with an average age of 25.71 years (SD = 5.25 years). Twenty-two participants were right-handed, and the other participants were left-handed. Nevertheless, all participants operated the computer mouse using their right hand and the keyboard using their left hand. Since we investigate how one's expectation of latency influences the course of the gaming session, one must be at least familiar with the concept of latency in video games. Therefore, to take part in our study, participants had to have at least 100 hours of experience in CS:GO. Participants experience in CS:GO ranged from 100 hours to 2895 hours, with an average of 535.16 hours (SD = 556.68 hours). Besides mere playtime, participants were also screened for their rank in CS:GO. CS:GO has an ELO-based ranking system with 19 internal ranks - 19 being the lowest and 1 being the highest possible. Participants' ranks ranged between rank 1 and rank 12. On average, participants were ranked on rank 9.59 (SD = 4.52), which corresponds to a medium rank overall.

4 RESULTS

Twenty-four participants played four rounds of CS:GO with different levels of phantom latency. Thus, we collected 96 responses to the post-experience questionnaire and 96 recorded performance measurements.

In the following, we present the descriptive and statistical analysis of the game experience measures. Then, we continue by reporting the analysis of performance measures. Finally, we conclude by outlining the qualitative feedback received in the study.

Figure 1: Shows two screenshots from the first-person shooter game *Counter-Strike: Global Offensive*. The left side of the figure shows an unaltered screenshot. The right side shows a screenshot with our latency overlay enabled in comparison. In this screenshot 30 ms of latency are depicted in the upper right corner of the game using numerical values (green). The red box, the red arrow, and the "Phantom Latency" description were not shown in an actual gaming session.

4.1 Game Experience Questionnaire

Descriptive data showing the mean score and standard deviation for each sub-scale of the *GEQ* and each level of PHANTOM LATENCY is shown in Table 1. Answers were given on a 5-point Likert scale (0 minimum, 5 maximum).

For statistical analysis we used a one-way ANOVA (PHANTOM LATENCY: *30 ms*, *60 ms*, *90 ms*, and *120 ms*) as no prerequisite for ANOVA was violated (Shapiro-Wilk test for all GEQ measures $p > 0.05$). ANOVA showed a significant effect of PHANTOM LATENCY on *Tension* (F(3,92) = 4.599, $p = 0.004$, $\eta_p^2 = 0.131$), on *Competence* (F(3,92) = 13.985, $p < 0.001$, $\eta_p^2 = 0.313$), and on *Positive Affect* (F(3,92) = 7.225, $p < 0.001$, $\eta_p^2 = 0.191$). We found no statistically significant effect of PHANTOM LATENCY on *Flow* (F(3,92) = 0.819, $p = 0.487$, $\eta_p^2 = 0.026$), on *Challenge* (F(3,92) = 1.633, $p = 0.187$, $\eta_p^2 = 0.051$), on *Negative Affect* (F(3,92) = 1.031, $p = 0.383$, $\eta_p^2 = 0.033$), and on *Sensory* (F(3,92) = 1.015, $p = 0.390$, $\eta_p^2 = 0.032$).

Next, we further investigated all significant results via Tukey tests. P-values and confidence intervals are corrected for multiple comparisons. Tukey's test showed significant differences between 30 ms and 120 ms (p_{Tukey} = 0.006, d_{Cohen} = -0.967, CI95=[-1.521, -0.186]) of PHANTOM LATENCY and between 60 ms and 120 ms (p_{Tukey} = 0.026, d_{Cohen} = -0.826, CI95=[-1.396, -0.729]) for the *Tension* subscale. For the *Competence* subscale, we found significant difference between 30 ms and 90 ms (p_{Tukey} = 0.007, d_{Cohen} = 0.957, CI95=[0.127, 1.081]), between 30 ms and 120 ms (p_{Tukey} = 0.001, d_{Cohen} = 0.815, CI95=[0.669, 1.623]), between 60 ms and 120 ms (p_{Tukey} < 0.001, d_{Cohen} = 1.254, CI95=[0.315, 1.268]), and, between 90 ms and 120 ms (p_{Tukey}=0.019, d_{Cohen}=0.858, CI95=[0.065,1.018]) of PHANTOM LATENCY. For the *Positive Affect* subscale we found significant difference between 30 ms and 120 ms (p_{Tukey} < 0.001, d_{Cohen} = 1.254, CI95=[0.337, 1.288]) as well as between 60 ms and 120 ms (p_{Tukey} = 0.012, d_{Cohen} = 0.959, CI95=[0.128, 1.080]). Figure 2 shows the results of the post-hoc comparison for *Tension*, *Competence*, and *Positive Affect*. Participants were significantly more tense in 120 ms PHANTOM LATENCY condition than in the 30 ms and 60 ms condition. Furthermore, participants had the significantly lowest feeling of competence when playing with the highest level of PHANTOM LATENCY. Lastly, we also found that playing with 120 ms PHANTOM LATENCY led to a significantly lower *Positive Affect* associated with the gaming session compared to playing with 30 ms and 60 ms.

4.2 Player Performance

Mean *Score*, mean *Kills*, mean *KD-Ratio*, mean *NoH* and, mean *DpH* for each level of PHANTOM LATENCY are shown in Table 2.

We again used a one-way ANOVA (PHANTOM LATENCY: *30 ms*, *60 ms*, *90 ms*, and *120 ms*) to investigate for statistical differences as ANOVA prerequisites were not violated (Shapiro-Wilk test $p > 0.05$). ANOVA revealed no significant effect of PHANTOM LATENCY on *Score* (F(3,92) = 2.387, $p = 0.074$, $\eta_p^2 = 0.072$) and *Kills* (F(3,92) = 2.694, $p = 0.051$, $\eta_p^2 = 0.081$). However, ANOVA detected significant difference in the data of *KD-Ratio* (F(3,92) = 3.873, $p = 0.012$, $\eta_p^2 = 0.112$), *NoH* (F(3,92) = 3.330, $p = 0.098$, $\eta_p^2 = 0.023$), and *DpH* (F(3,92) = 3.136, $p = 0.029$, $\eta_p^2 = 0.093$). Next, we used Tukey's test to conduct a post-hoc comparison for all significant ANOVA results. P-values and confidence intervals, again, are correct for multiple comparisons. Tukey's test revealed significant differences in *KD-Ratio* (p_{Tukey} = 0.016, d_{Cohen} = 0.876, CI95=[0.072, 0.994]), in *NoH* (p_{Tukey} = 0.028, d_{Cohen} = 0.820, CI95=[0.424, 10.326]), and in *DpH* (p_{Tukey} = 0.041, d_{Cohen} = 0.775, CI95=[0.072, 5.646]) between 30 ms and 120 ms of PHANTOM LATENCY. Participants playing with 120 ms of PHANTOM LATENCY had a significantly worse kill-to-death ratio (meaning they died more often while eliminating fewer enemies), hit significantly fewer headshots, and dealt significantly less damage per shot in general compared to playing with 30 ms of PHANTOM LATENCY.

4.3 Qualitative Feedback

After each 10-minute round of playing CS:GO with one of the four levels of PHANTOM LATENCY, participants were asked if they felt latency in the last round and, if so, how they felt that the latency in the game manifested itself, i.e., what effect it had. Out of all 96 individual rounds played, participants felt latency in 43 rounds

	Game Experience Questionnaire Scores						
Phantom Latency	**TEN**	**COM**	**FLO**	**CHA**	**POS**	**NEG**	**SEN**
30 ms	0.54 ± 0.53	2.64 ± 0.59	3.48 ± 0.52	2.11 ± 0.81	2.54 ± 0.69	0.39 ± 0.49	1.25 ± 0.59
60 ms	0.66 ± 0.65	2.29 ± 0.46	3.51 ± 0.53	2.22 ± 0.82	2.33 ± 0.49	0.43 ± 0.54	1.02 ± 0.62
90 ms	1.04 ± 1.12	2.04 ± 0.46	3.41 ± 0.78	2.04 ± 0.75	2.14 ± 0.58	0.68 ± 0.87	1.00 ± 0.55
120 ms	1.39 ± 1.07	1.51 ± 0.69	3.25 ± 0.59	2.51 ± 0.87	1.73 ± 0.75	0.42 ± 0.67	0.83 ± 0.58

Table 1: Shows the mean scores and standard deviation of the sub-scales *Tension* (TEN), *Competence* (COM), *Flow* (FLO), *Challenge* (CHA), *Positive Affect* (POS), *Negative Affect* (NEG) and *Sensory* (SEN) of the *Game Experience Questionnaire* for each level of tested Phantom Latency.

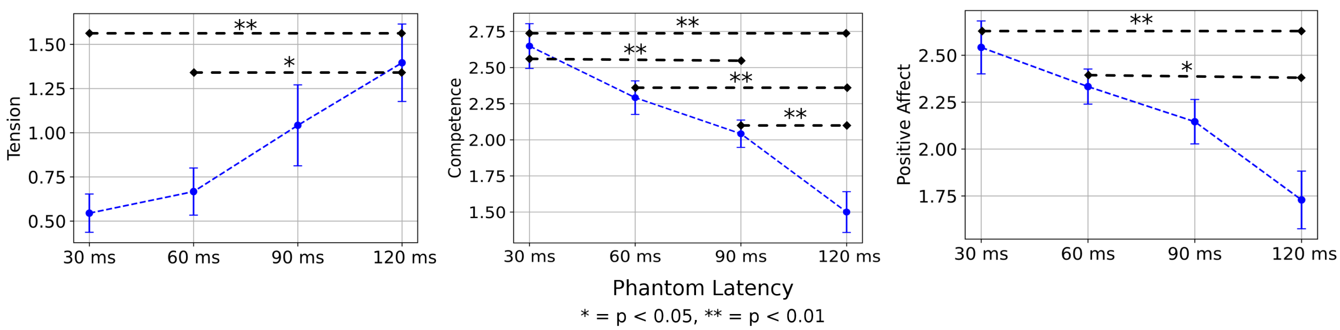

Figure 2: Scores given in the *Tension*, *Competence*, and *Positive Affect* subscale of the *Game Experience Questionnaire* [23]. Significant differences are highlighted via asterisks. Error bars show the standard error. Participants were significantly more tense in 120 ms phantom latency condition than in the 30 ms and 60 ms condition and had the lowest feeling of competence when playing with the highest level of phantom latency. We also found that playing with 120 ms phantom latency led to a significantly lower *Positive Affect* associated with gaming session compared to playing with 30 ms and 60 ms.

	Performance Measures				
Phantom Latency	**Score**	**Kills**	**KD-Ratio**	**NoH**	**DpH**
30 ms	552.04 ± 117.85	47.67 ± 10.41	2.72 ± 0.59	22.42 ± 7.48	21.84 ± 5.78
60 ms	521.83 ± 106.39	44.33 ± 10.34	2.17 ± 0.53	18.92 ± 6.01	20.81 ± 4.51
90 ms	497.79 ± 108.71	41.71 ± 10.09	1.91 ± 0.71	17.46 ± 6.81	19.31 ± 3.31
120 ms	469.71 ± 110.94	39.99 ± 10.04	1.74 ± 0.59	17.04 ± 5.78	18.98 ± 3.68

Table 2: Shows the mean and standard deviation of *Score, Kills, KD-Ratio, Number of Headshots* (NoH), and *Damage per Hit* (DpH) for each level of tested Phantom Latency.

(44,79 %). Nineteen participants (79.167 %) felt latency while playing with 120 ms of Phantom Latency and 15 participants (62,5 %) were sure there was latency when playing with 90 ms of Phantom Latency. Still, seven rounds (29.167 %) were associated with latency, while a suggested Phantom Latency of 60 ms was presented to the participant. In the 30 ms Phantom Latency condition only two participant (8.333 %) felt latency. Crucially, all participants played with the same actual latency of 75 ms in all rounds. Increasing the amount of displayed latency also increased the likelihood of participants feeling the effects of latency. The higher the displayed latency, the higher the ratio of participants reporting to have felt it in the last gaming round.

5 DISCUSSION

Our results consistently show that phantom latency - a latency merely suggested and displayed to the player - has significant effects on the game experience and performance. In this section, we first discuss and contextualize phantom latency's effects on the feeling of tension and competence. We continue to shed light on how phantom latency alters the positive feelings associated with the game. Next, we discuss the effects of phantom latency on the objectively measured player performance. We showcase the implication of our findings for researchers, game developers, and gamers alike. We conclude this section by discussing our study's limitations and possible future works.

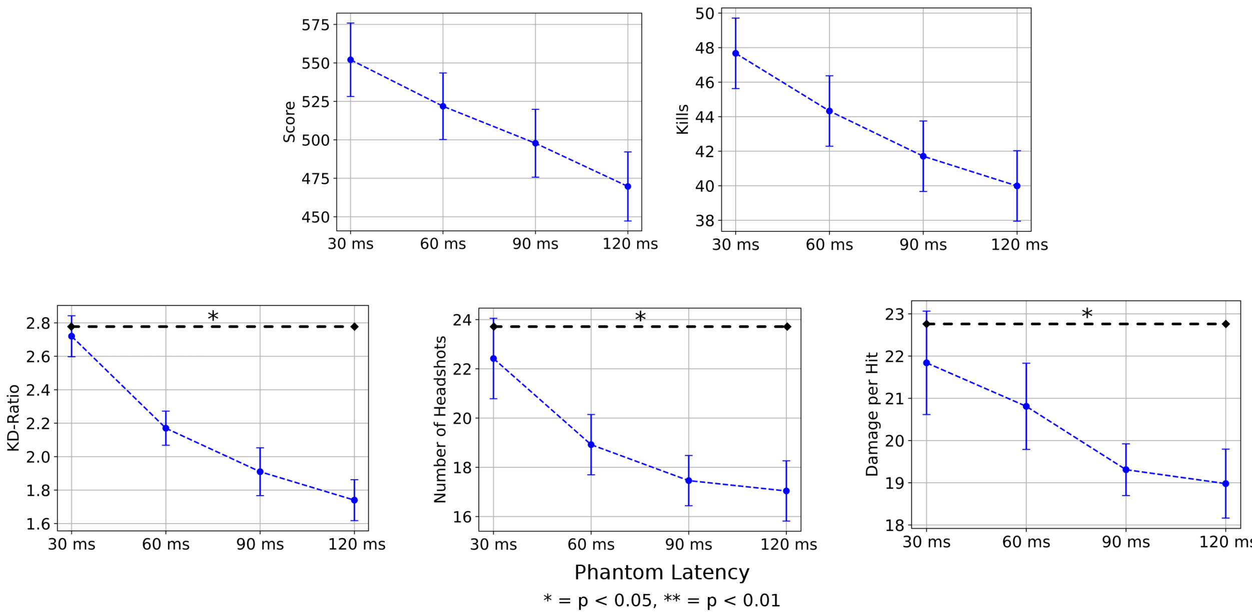

Figure 3: Performance reached by the participants in the respective metric: *Score, Kills, KD-Ratio, Number of Headshots,* and *Damage per Hit.* Error bars show standard errors. Significant pairwise comparisons are highlighted via asterisk. Participants playing with 120 ms of Phantom Latency had a significantly worse kill-to-death ratio, hit significantly fewer headshots and dealt significantly less damage per shot in general compared to playing with 30 ms of Phantom Latency.

5.1 Effects on Tension, Competence, and Positive Affect

Our work shows that players were tenser when playing with 120 ms than when playing with 30 ms or 60 ms of phantom latency. We also found the same systematic regarding the positive affect associated with the game - players achieved a lower positive affect score when playing with 120 ms of phantom latency compared to playing with 30 ms and 60 ms of phantom latency. Lastly, we also found that phantom latency altered how competent players felt while playing. Playing with the highest level of phantom latency (120 ms) lead to a significantly reduced feeling of competence compared to playing with 30 ms, 60 ms, or even 90 ms of phantom latency.

Our findings regarding the experienced tension and the associated positive affect align with previous work, which showed that true latency increases tension and reduces all positive feelings and emotions towards digital video games [18]. A reduced positive affect indicates that the players experienced less joy and pleasure and generally reduced perceived fun of playing the game [23]. The enjoyment of an activity has a systematic influence on the performance during this activity [5] - this is known as the performance-enjoyment link in video games [45, 47]. Our work extends prior work and shows that the effect of latency on the game experience is not entirely technically but at least partly expectation-based. The mere suggestion or presentation of latency, as done in our work via our custom latency overlay, is enough to induce an expectancy-based effect, significantly altering the experiences obtained in the gaming session. Evidently, we also found that phantom latency reduced the subjective feeling of competence in our study's players. This is particularly interesting because all tested players were highly skilled and played at least 100 hours of *Counter-Strike: Global Offensive* (mean = 535.16 hours, SD = 556.68 hours). One possible origin of the effects of phantom latency on the feeling of competence is that players may tried to adapt to the phantom latency based on prior experience with true latency. One could assume that all players knew how true latency manifests in the game and which techniques usually work to compensate for it (such as over- or undershooting). Since our study always had the same true latency of 75 ms, previous experience with latency did not provide any advantage and may even result in a reduced feeling of competence. Players may tried to adapt to a varying latency, which ultimately was constant.

We did not find a significant effect of phantom latency on the other subscales of the *Game Experience Questionnaire* [23]. This indicates that the subscales *Sensory*, *Flow*, *Negative Affect*, and *Challenge* are either not susceptible to phantom latency or a expectation-based effect in generally. However, given our results, it is not possible to determine this conclusively.

5.2 Effects on Game Performance

Our findings consistently show an effect of phantom latency on gaming performance. In line with other work researching the effects of true latency in video games, we show that players were less accurate and less effective when playing with the highest phantom latency (120 ms) compared to playing with its lowest level (30 ms). In addition, players had a significantly worse kill-to-death ratio, hit significantly fewer headshots, and subsequently dealt significantly less damage per hit.

However, contrary to previous work, which showed that true latency directly influences game performance [7, 10, 18], our work shows that the players' performance seems to be less affected by phantom latency. This behavior was somewhat expected since the performance is a hard quantitative measure and less prone to subjective manipulation [29]. Nevertheless, phantom latency significantly and negatively influenced gaming performance at its highest level. The effects of phantom latency on the game performance can be explained using the classical placebo, respectively nocebo, paradigm. Players in our study performed worse because they anticipated performing worse based on their experience with the game. The players' expectations of performing in a specific condition ultimately manipulated how they performed. The number of given headshots demonstrates the successful suggestion of latency by our latency overlay. A headshot in CS:GO is the purest form of skill and competence in the game since it is exceedingly hard to hit a target as small as the head when enemies are moving around. While it is almost impossible to hit such a small target (depending on how far away the enemy is) when playing with 120 ms true latency, our induced phantom latency would not have a technical effect. Nevertheless, players in the 120 ms phantom latency condition hit significantly fewer headshots than in the 30 ms phantom latency condition. This again demonstrates the performance-enjoyment link discussed in the game experience section. Players not only felt less competent after playing a round with high phantom latency, but they also actually behaved less competent, as showcased by the significantly reduced amount of hit headshots.

5.3 Implications for Researchers and Game Developers

Our findings have implications for researchers and game developers. Firstly, video game researchers profit from our findings since we show that the expectation of a gaming session may fundamentally change the course of a session. This may be relevant when investigating novel interfaces, new game mechanics, or game elements. Latency researchers, in particular, benefit from our work as we show that latency has an inherent expectancy-based component. This is especially the case when testing experienced players who are used to the game or system behaving in a certain way. We conclude that it thus may be best to keep the participants blind to the actual study's goal when investigating latency, as the mere expectancy of latency may already alter the study's outcome. Finally, our findings are also relevant to previous work investigating the effects of latency in interactive systems. Since previous work did not directly account for the nocebo effect of latency, some of the results may overstate the effect of latency. While it is undoubtedly true that latency has a real effect, revisiting previous approaches to latency and its compensation may be worthwhile with the expectancy-based effects in mind.

Secondly, game developers should also be aware of the effect of displaying latency. Based on our findings, displaying latency may not always be advisable when optimizing for game experience. A poor game experience has consequences - not only for players but also for game developers and publishers. In the severest scenario, an unsatisfactory game experience will result in the game being canceled [9, 16, 30]. A range of current video games, such as *Fortnite* [17] and *PlayerUnknown's Battleground* [24] already aim to disguise latency using color-switching icons instead of textual values. However, it is unclear if concealing latency using an icon is enough to prevent players from forming an expectation about latency in the game.

5.4 Limitations and Future Work

Our work demonstrated an effect induced by the expectancy of latency in video games. Nevertheless, our work has limitations, presenting new avenues to investigate expectancy-based effects in video games.

In medicine, placebo (placebo vs. baseline) or placebo-controlled (placebo vs. active treatment) studies require at least two controlled groups of conditions [28, 29]. Such a study design allows researchers to compare a potential placebo effect against an actual and no treatment. Our study only investigated the effects of suggested latency (phantom latency) in a within-subject study design without a dedicated control group. This approach is valid because the actual effects of true latency in video games, especially in CS:GO, have been demonstrated numerous times by previous work [32, 33]. Nevertheless, conducting a placebo-controlled study investigating latency in video games may allow comparing the true and the expectancy-based effect of latency. Thus, we encourage future work to investigate expectancy-based latency effects in a placebo-controlled study that operationalize the treatment (true latency vs. phantom latency) in its design.

Furthermore, since the placebo and nocebo effect are entirely based on the participants' expectations, we can not conclusively be certain about their origin. Our work showcased an expectancy-based effect of phantom latency. However, we can not be sure what triggered the effect. As we postulate and discuss, it is possible that the expectancy of latency decreased gaming experience and performance. On the other hand, it is also possible that the lack of latency variation negatively influenced our participants. Participants expected and anticipated varying levels of latency in the study; as soon as the gaming session started, those expectations were violated, possibly leading to a decrease in experience and performance. While this may be another possible explanation for our findings, we concluded that it is highly unlikely. Considering that 79.168 % of the participants were sure that they felt latency while playing with 120 ms of phantom latency, it is implausible to assume that the participants' expectations were explicitly violated. Nevertheless, it may be beneficial to investigate further what circumstances allow and support the formation of an expectancy-based latency effect.

In our work, we controlled for the players' individual skill in CS:GO to increase the work's reliability and validity. Nevertheless, it is possible that skill influences the formation of expectancy-based latency effects beyond our control mechanisms. In our study, we investigated the effects of phantom latency on players ranked 1 to 12 in CS:GO's internal ranking system. However, while all of our participants can be considered high-skilled players, there still is a difference in experience, technique, and play style between a rank 1 player and a rank 12 player. Thus, future work should investigate how phantom latency affects game experience and performance if all tested players are on the exact same skill level.

Lastly, since we found that phantom latency induces a quantifiable expectancy-based effect, the next natural step would be to investigate if placebo effects can be used to reduce the adverse effects of true latency. Latency compensation in video games is a growing field [18, 34, 48] since the adverse effects of latency have become more relevant in the eye of new gaming paradigms such as cloud-based and mobile gaming. A positive placebo effect of latency compensation techniques could be investigated by, for example, conducting a study in which participants play a video game with true latency and actively priming the participants that they are playing with no latency or a novel latency compensation method.

6 CONCLUSION

This paper presents a study with 24 participants playing *Counter-Strike: Global Offensive* with phantom latency. In our study, we primed participants with four levels of phantom latency (30 ms, 60 ms, 90 ms, and 120 ms) using a self-developed latency overlay, while the true latency in the gaming session was not manipulated and stayed consistent in all conditions. We found that the mere suggestion of latency significantly and bidirectionally influences the participants' game experience and performance. Participants were significantly tenser, felt less competent, and associated the game with significantly less positive feelings the higher the amount of phantom latency. Besides the subjective quality of experience, we also found that participants' objective performance was lowered by phantom latency. They achieved a significantly reduced kill-to-death ratio, hit fewer headshots, and dealt less damage per hit when playing with the highest level of phantom latency. We discuss our findings and conclude implications for researchers and game developers. We discuss that it may not always be the best approach to display latency to players if one wants to optimize game experience and performance. Furthermore, we discuss that previous work investigating latency may overstate latency's technical effects by not accounting for its expectancy-based component. Researchers must be aware that a participant's expectancy of the system or part of the system (such as latency) can alter the outcome of an investigation.

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