Hexed by Pressure: How Action-State Orientation Explains Propensity to Choke in Super Hexagon

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Many videogames require players to perform under pressure; however, not all players respond equivalently to pressure: why are some players more likely to tilt (lose control during play) or choke (perform poorly relative to their ability) whereas others seem to thrive under pressure? Given the importance of both emotion regulation in tilting and optimal arousal in achieving optimal performance, we propose that individual differences in ability to down-regulate negative affect under stress—known as failure-related action-state orientation (fASO)—could explain propensity to choke under pressure. We conducted an online between-subjects experiment (N=144) in which we measured baseline performance in Super Hexagon (day 1), then exposed participants to a stress induction (i.e., PASAT-C) or had them play a low-intensity bubble-popping game before playing again (day 2). Under stress, players higher in fASO performed better relative to their baseline in terms of average time alive and stalled progress; whereas, without stress, players lower in fASO performed better on both measures. Traits reflective of proposed explanations for choking (i.e., reinvestment, attentional control) did not influence performance under pressure. The ability to down-regulate negative affect and overcome setbacks is a useful theoretical lens to explore why some players choke under pressure, whereas others thrive.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**; **Empirical studies in HCI**; *HCI theory, concepts and models.*

Additional Key Words and Phrases: Videogames, Action-State Orientation, Individual Differences, Tilting, Choking, Clutch, Stress

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1 INTRODUCTION

In videogames, players frequently encounter high-pressure scenarios in which the maintenance of their performance is crucial. For example, a player may suddenly find themselves face-to-face with an elite enemy—as the last remaining teammate in a white-knuckled deathmatch—or staring down the final seconds of a timer as they race to complete a level. Under these conditions, even a seasoned player in an advantageous position might "choke": a sudden underperformance when it is least desired. This is a common experience in videogames of all genres—and the stakes are magnified in esports contexts, wherein players must prevail under the scrutiny of hundreds, thousands, or hundreds-of-thousands of spectators. However, even in a high-pressure situation like this, not everyone is prone to choking. For some players, the pressure enhances their performance—allowing them to "clutch".

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Why do some players succumb to the pressure, while others thrive? Recent work focusing on how choking and clutching manifests in competitive digital games [15, 107] has found that various traits and backgrounds are associated with choking and clutching. However, work has so far not integrated a crucially relevant theory that could explain why similar circumstances result in vastly different responses depending on individual disposition—namely, that of *action versus state orientation (ASO)*, which describes individual differences in the ability to self-regulate [82]. ASO describes two such self-regulatory abilities that relate to 1), the ability to enact one's intentions (demand-related ASO) and 2), the ability to overcome rumination after failure (failure-related ASO) [82]. Both abilities depend on the capacity to self-regulate affect [58]. On one end of the spectrum is *state orientation*, which is related to the inability to end unwanted affective states and may involve a state of indecision and hesitation (demand-related ASO) or rumination over an undesirable experience (failure-related ASO) [58]. *Action orientation* represents the other end of the spectrum and is related to one's capability to overcome unwanted affective states [82]. ASO has been studied in several contexts, including athletic performance, and in particular, performance under pressure. In general, state-oriented athletes are likely to have difficulty implementing their intentions (demand-related state orientation), or ruminate over failure (failure-related state orientation), and as a result, they perform worse when faced with too much pressure [58]. While state-oriented athletes may be similarly capable in the absence of stress, action-oriented athletes are generally better able to perform well under pressure [61], scoring more reliably in critical game situations [102], and generally performing more consistently [11]. We propose that ASO could be similarly relevant in videogames—a player's ability to self-regulate could be at the root of one's propensity to choke under pressure.

Past work exploring choking has focused on the context of competitive multiplayer games and esports, which encompass complex, multi-pressured, and high-stakes situations with many opportunities for performance failures. However, it is also critical that we understand performance under pressure in single-player contexts—wherein the player experience may likewise be moderated by challenge, pressure, and failure [50]. As such, to explore choking under pressure in a new context—and to ensure a high degree of controllability and reproducibility in our study—we chose to use a clone of Super Hexagon: a single-player game that is easy to learn but challenging and, as with competitive titles, replete with opportunities for underperformance.

In this work, instead of pressure coming from spectators, teammates, or opponents (as it does in online multiplayer games), we employ a standard stress induction [86] to explore how differing levels of stress relates to performance when considering one's failure-related action-state orientation (fASO). Participants first completed a five-minute baseline session of Super Hexagon before either completing five minutes of the stress induction task or a simple bubble-popping game. Immediately after, they completed another five-minute session of Super Hexagon. To compare action-state orientation to other traits previously related to choking under pressure, we also measured tendencies toward reinvestment [91] and attentional control [38]. We were interested in determining if the effects of stress were moderated by fASO or any other personality traits associated with choking under pressure.

Because the game we are using to study performance under pressure differs from the types of games previous scholars have written about (i.e., sports and competitive multiplayer games), and responses to stress are multifaceted, we asked players to reflect upon the mistakes they were making when they were performing below their expectations. Participants described a variety of mistakes, relating to choosing specific actions, carrying out movements, attention shifts, or issues relating to the game's design. They further reflected on their own mental or physical state, their general lack of experience, how their performance on a previous attempt affected later attempts, memorization, or self-described motivation.

Our work extends past work by exploring the relationship between fASO and performance under pressure in digital gaming. We demonstrated that performance under pressure was significantly moderated by fASO, showing the relevance of one's ability to self-regulate affective state after failure. We additionally compared fASO to other traits previously related to performance under pressure (reinvestment, and attentional control), finding no support for these traits as a predictor of in-game performance in Super Hexagon. We suggest that, while traits such as reinvestment and attentional control may be more appropriate for the assessment of *specific* channels of failure, *ASO* allows for more *general* (or broadly applicable) insights into performance — and thus may be useful for evaluating performance under pressure more widely.

2 RELATED WORK

Many players have a strong interest in performing well in the games they play. Performance is generally linked to challenges; and challenge, for many players, is a crucial factor towards enjoyable games [37]. For example, flow theory suggests that when challenge and abilities are in balance, a state of flow, where players are fully immersed in the experience, is likely to occur [46, 94]. This is a highly enjoyable experience that can contribute to player well-being [42]. However, finding the optimal level of challenge for each player is not an easy feat to achieve, and is made even more difficult when players behave differently when playing under pressure.

This pressure can come from many different sources. Consider, for example, esports titles that draw in millions of viewers worldwide — the pressure on esports athletes in these conditions is relentless [89, 107]. In games research, much of the literature has investigated the phenomenon in the context of competitive formats. Here, spectators, teammates, and opponents often represent the perceived pressures [15]. In esports, these pressures are amplified by circumstances unique to esports athletes — introducing financial pressures constituting ongoing employment, salaries, sponsorships, and cash prizes [14]. However, pressure is not unique to this context — Making mistakes in competitive gameplay, even for casual players, is also a common reason for tension and abusive communication in multiplayer games [77, 99, 115]. Pressure does not necessarily need to come from outside the individual and there are a multitude of factors that may influence player performance.

Performance pressure — regardless of its source — can lead gamers to experience instances of decreased performance [7]. Specific states that have been described in this context are "choking" [15] or "tilting" [123]; these two concepts are similar — both describe how performance decreases temporarily under potentially difficult circumstances. Tilting is an emotional state constituting frustration and lack of control that leads to poor performance [45, 78, 123], whereas choking is more closely related to experiences of pressure and anxiety [7, 15, 92]. On the other hand, some players even exceed expectations under pressure, performing better than usual, which is referred to as "clutching" [15]. In this section, we describe how performance alters under pressure, as well as theoretical explanations for differential performance under pressure.

2.1 Performing Under Pressure

Three different responses to pressure that have been observed in digital games are "clutching", "choking", and "tilting".

2.1.1 Clutching. Clutching describes the phenomenon of a player under pressure performing better than they usually would [97]. Clutching is compared to the flow state (e.g., [94]) because both states involve confidence, absorption, and enjoyment. How one arrives at a clutch state, however, differs from flow states. Some have described clutch states as "making it happen" states because it is a purposeful, effortful and intense state [110]. Clutch states are characterized by a complete and deliberate focus, intense effort, heightened awareness, heightened arousal, an absence of negative thoughts, and the automaticity of skills [110]. As such, clutching is more likely to occur amongst skilled athletes or players who purposefully hone such a state. Propensity to clutch is also positively associated with increased experience with competitive gaming, and negatively associated with social anxiety [15].

In high-pressure situations, clutching is necessarily more difficult to achieve—as it is more likely to occur with intention, increased experience, and confidence in the task at hand—than its opposite: choking, which doesn't have such barriers.

2.1.2 Choking. Choking refers to scenarios in which an individual fails to maintain their performance where it is expected or highly important [7, 15]. The concept has been studied extensively in sports scholarship [52, 59], and occurs predominantly in situations wherein there is both pressure to perform and an increase in anxiety [92]. As pressure is a fundamental antecedent to choking, choke typically manifests in situations wherein an individual feels it is essential to perform well [7]. Notably, susceptibility towards choking varies among individuals, owing to variances in traits, expertise, and familiarity with the task at hand [15, 36].

Alongside physical sports, recent inroads have been made toward understanding how choking manifests in competitive digital games and esports [15, 107]. To this end, Beres et al. [15] found that self-rated propensity to choke was positively correlated with player trait tendency towards reinvestment and public self-consciousness. Their study further suggests that many of the choking outcomes within physical sports scholarship may be reproducible in competitive videogames, owing to a great many parallels between both domains (e.g., competition, execution of mechanical and strategic skills, opponents and teammates, spectators, and so on). Furthermore, Sharpe et al. [107] find that performance pressures (such as a live audience) elicited breakdowns in performance among both university- and national-level esports athletes, although the effects were more pronounced for the university competitors.

2.1.3 Tilt. Tilt refers to an emotional state that players can enter in response to poor performance, either the player's own performance or the performance of others [45, 123]. Falwell [45] describes three triggers of tilt: a lack of control, a failure to meet expectations, and a negative environment within the game. Tilt is associated with feelings of anger or frustration [45, 123]. While tilt has been adopted as a colloquialism broadly in videogames, the term originates from pinball, in which a lack of control in a context of frustration could result in the player "tilting" the machine, which would freeze the flippers and result in draining a ball [41]. Before application in videogames, tilt was studied in poker—where, as in videogames, "going on tilt" was used to describe a loss of control through emotionally-charged, irrational, and ultimately detrimental decision-making [26, 98].

Research has found that tilt in poker is associated with both unhealthy play behaviours (e.g., disordered gambling) and worse performance outcomes [26, 93]; however, it may be meaningfully managed (as it is by successful professionals) through the adoption of positive emotion regulation strategies [26]. In digital games, Wu et al. speculate that tilt may likewise contribute to incidences of toxicity (i.e., abusive or harassing behaviours directed to other players) [123]. This toxicity may be prompted by a belief that the game is lost—once a player has reached a state of tilt, they often believe that they have already been defeated [87]. However, as with poker, tilt may be managed in digital games: Wu et al. [123] find that players who perceive tilt as malleable (that is, within their control) are more likely to respond positively—by re-centring their emotions, viewing tilt as an opportunity for learning, and shifting focus to what they can control within the game.

2.2 Explanations for Altered Performance Under Pressure

Prior research on choking and tilting has posed a variety of explanations for why performance is altered under pressure. Several specific responses to pressure that lead to poor outcomes and performance have been identified [36, 92]. These include *getting distracted, shifting attention towards explicitly monitoring rather than relying on automatic processing (reinvestment),* and *worrying about self-presentation.*

Distraction occurs when pressure redirects one's attention and working memory resources towards thoughts of worries about one's own performance [36]. Attention may also shift toward irrelevant stimuli [92].

Explicit monitoring also involves a shift of attention to internal processes relating to the execution of the skill [7, 36, 92]. Instead of making use of well-developed procedural memory to complete the task that allows for efficient and automatic processing, players may switch to a slower, more deliberate form of processing that relies upon declarative knowledge of how to carry out a task [2, 7, 105, 108]. This is also known as reinvestment theory—which proposes that a learner reverts to an earlier stage of learning when faced with pressure [90, 91].

Self-presentation refers to worry relating to how the player is being perceived and evaluated by others [103], and is both a potential cause for increased pressure, as well as something that shifts one's attention away from carrying out a task, leading to reduced performance [92]. Self-presentation is more relevant when players are being observed in some way; it is essentially a form of social anxiety where the player is distracted by worries relating to maintaining one's identity as an athlete [92]. Being observed also has the potential to enhance performance—past work found that players' performance improved while being observed [21, 72]. Other past work found no difference in performance when being observed [43]. These conflicting results point to a greater need to understand how players respond to pressure.

A common feature of these explanations is *shifting attention*. Sometimes one's attention drifts towards worries about one's performance [36], sometimes it shifts towards thinking about the mechanics of movement [91], and sometimes it shifts towards social evaluation [103].

Anxiety is another reason why attention might shift under pressure. The presence of anxiety has been previously related to deficits in parsing stimuli, making decisions, and carrying out actions [96]. In terms of parsing stimuli, anxious individuals are more easily distracted by task-irrelevant information [63], and threatening stimuli are given extra attention [1] and are harder to disengage from [47]. Furthermore, stimuli are more likely to be viewed as threatening [18, 19, 96], and anxious individuals will fixate on threatening targets for less time [118], resulting in a less accurate response [13]. Additionally, because attention is drawn away from relevant information, people are less able to select an appropriate response and the responses they do make are biased towards specific threat-related responses [96].

2.2.1 Arousal and Performance. One variable that is particularly relevant to performance under pressure is *arousal*. Arousal is the intensity dimension of activity within an organism which ranges from low (e.g., sleeping, boredom, etc.) to high (e.g., stress, anxiety, excitement, etc.) [121]. Arousal can be seen as a more unspecific variable that encompasses any form of activation, regardless of whether it comes from internal standards, anxiety, external pressure, being observed, or physiological factors (e.g., [10, 106, 116]). As such, arousal should be related to several, if not all of the aforementioned factors and can help explain how they might have additive effects. According to the *Yerkes-Dodson Law* [124] a certain amount of arousal is beneficial for performance, but only up to a point, after which arousal becomes too high and the performance drops again. This relationship is visualized as an inverted "U"-shape, as it is not linear: performance is best when the level of arousal is medium, but worse when arousal is too low or too high. However, task difficulty is relevant to this relationship—if a task is easy, then adding pressure to it can improve performance; if the task is already difficult, then adding more pressure should result in performance deteriorating [124].

Calabrese [30] has related the Yerkes-Dodson law to findings from biopsychology that describe how hormones released under stressful conditions affect learning and memory (including declarative memory, attentional/working memory, and emotional memory). This suggests that arousal might be related to previously mentioned attentional shifts. Individuals strive to reduce arousal when it is too high, for example by seeking relaxation or shifting attention; and they strive for more stimulation when arousal is too low [121], which can be achieved by adding difficulty or pressure.

2.3 Individual Differences in the Stress Response: Action-State Orientation

However, even if every outside variable could be controlled for, different players can have different responses to pressure and the same situation will not have the same effect on everyone. While main effects can inform us about general tendencies of a population, they can also limit our understanding, when they lead to the suggestions of one-size-fits-all solutions. The scientific literature has provided many suggestions for trait measures that differentially influence performance.

One such example is *action-state orientation* (ASO) as described by *self-regulation theory* (also referred to as action control theory) [82, 83, 85]. ASO describes individual differences in self-regulatory abilities [84]. When an individual is experiencing stress, self-regulation becomes crucial (see [12]). Individuals with good self-regulatory skills (action-oriented individuals) are likely to respond well to stress [49] while state-oriented individuals struggle with self-regulation and are more likely to thrive in low-stress situations [53, 68]. Two types of ASO can be distinguished: *demand-related* action-state orientation [69, 73] and *failure-related* action-state orientation [28]. Both types of ASO represent a spectrum rather than a dichotomous expression and are seen as two independent abilities [81]. Demand-related ASO (dASO, also often referred to as decision-related ASO or AOD) is relevant in situations that are characterized by the absence of positive affect (e.g., feelings of listlessness or frustration) [73]. Demand-related action-oriented individuals are better at overcoming such a state of inaction by up-regulating their positive affect (self-motivating) [122], while demand-related state-oriented individuals are more likely to find themselves stuck in inaction [75]. This has been shown in the context of games by demonstrating that demand-related state-oriented individuals are less likely to dismiss a dialogue-box that interrupted their gameplay than action-oriented individuals [17].

However, when it comes to influences on player performance, especially under the threat of failure, failure-related ASO (fASO) is the more relevant ability to consider [27, 79]. Failure-related ASO is relevant in situations that are characterized by the presence of negative affect, such as feelings of helplessness or puzzlement [80]. This means that failure-related state-oriented individuals are likely to be overly critical and prone to rumination after experiencing a failure [9, 79]. Instead of moving on from a negative experience, they tend to over-analyze and find it hard to overcome the negative emotions. This is why failure-related state-oriented individuals struggle under stress and are likely to benefit from a more pressure-free environment, where self-regulation is not necessary. On the other hand, failure-related action-oriented individuals are good at down-regulating their negative affect (self-soothing or self-relaxation) [122] and therefore, can thrive under pressure. Failure-related state-oriented individuals have been shown to benefit from cheat codes as an external support in a challenging single-player game situation [120]. External support can remove pressure from a situation without affecting performance.

2.3.1 *Action-State Orientation in Sport.*

Recent research into clutching and choking in competitive gaming and esports has successfully drawn upon the existent literature on clutching and choking in traditional sports [15]. The effectiveness of considering action vs. state orientation has also been demonstrated in the domain of athletics and physical sports (in both casual play and professional play) to explain differences in performance under pressure (e.g., [11, 58]), and therefore this past work may be relevant to the present study.

The empirical evidence suggests that action-oriented athletes can, under most circumstances, better handle situations of increased pressure [58]. For example, action-oriented athletes performed better than state-oriented athletes when instructed to aim for a new personal record [56, 102]. In basketball, state-oriented players were more likely to pass the ball to a playmaker, while action-oriented athletes were more likely to aim towards the basket [100]. In a different study, experienced basketball players did not differ in their accuracy under normal conditions but state-oriented players performed worse after a self-focused attention induction [51]. Several studies have found such associations between action orientation and performance in sports [11, 57, 102], particularly with fASO [8].

In general, state-oriented athletes are more likely to ruminate over failure (fASO) or have difficulty making decisions (dASO) [58]. Under stress, state-oriented athletes are less able to control their behaviour, for example, by missing the best timing for a shot [11]. However, being action-oriented does not provide a universal advantage to performance. State-oriented athletes, due to the reduced ability to self-regulate, tend to expend their energy sooner [56, 57]. Under many circumstances, this is a downside, but in a 100-metre race, state-oriented athletes outperformed action-oriented athletes [8]. This is because action-oriented athletes are more likely to leave some of their energy in reserve [58]. Furthermore, the tendency to ruminate can lead to state-oriented athletes considering alternative strategies, and a greater capacity to play under a variety of different conditions [58].

2.4 Summary and Gap in Literature

There are myriad sources of performance pressure within digital games; from live audiences to internal pressure to succeed to pressure from prize winnings, teammates, or coaches in an esports context. These various pressures can lead to experienced stress among players. Performance pressure, alongside an increase in anxiety, can lead to players choking [7, 15]. Similarly, losing control (i.e., poor emotional regulation) in a game can lead to tilting [45, 123]. Tilting and choking are both common terms used in the context of videogames to describe performing worse than one's ability.

Explanations for choking include getting distracted and shifting attention toward thoughts about one's performance or the outcome [36]. Additionally, shifting attention toward deliberate execution of the skill rather than relying on automatic processing when under pressure (which can result in suboptimal performance) is known as reinvestment theory [91]. Furthermore, worrying about how one is being perceived by others can interfere with optimal performance [92]. These are all examples of players "getting in their heads" and shifting their attention, which can prevent optimal performance. Beyond shifting attention, too much psychological arousal has been known to impair performance [124], suggesting that down-regulation of arousal may be an important aspect of preventing choking under pressure.

Although players are all likely to experience choking at one point, some players are more prone to choking than others [15]. We propose that *individual differences in self-regulatory ability under stress could be at the root of propensity to choke, given the importance of both emotion regulation in tilting and of optimal arousal in achieving optimal performance.* These differences in self-regulatory ability under stress are described by action-state orientation [81]—in particular, by the ability to down-regulate negative affect, known as failure-related action-state orientation (fASO). In research conducted in the late 1980s and early 1990s, being higher in fASO was linked to thriving under pressure in a variety of physical sporting contexts [8, 11, 57, 102]. However, there has (to our knowledge) been no investigation of differences in self-regulatory ability—as characterized by fASO—as a potential source of inter-individual differences in propensity to choke. In this paper, we explore the role that fASO plays in choking during videogame play. Based on self-regulation theory, we expect that players higher in fASO (action-oriented players) would be more likely to perform well under stress; whereas players lower in fASO (state-oriented players) would be more likely to perform well without stress, generating the following hypothesis:

H1. Stress condition will moderate the effect of fASO on performance in Super Hexagon, with increased fASO (i.e., higher failure-related action orientation) being associated with better performance in the stress condition and worse performance in the non-stress condition.

Given the related literature on choking, we also investigate the role of attentional control, reinvestment, arousal, and the ability to up-regulate positive affect (i.e., dASO) in performance under stress, generating the following hypotheses:

H2. Stress condition will moderate the effect of dASO on performance in Super Hexagon, with increased dASO (i.e., higher demand-related action orientation) being associated with better performance in the stress condition.

H3. Stress condition will moderate the effect of reinvestment on performance in Super Hexagon, with increased reinvestment being associated with worse performance in the stress condition.

H4. Stress condition will moderate the effect of attentional control on performance in Super Hexagon, with increased attentional control being associated with better performance in the stress condition.

Additionally, we expected performance on day 2 to relate to performance on day 1, and for age to be negatively related to performance, due to declines in reaction time [113]. These assumptions were tested in our models, but are not contributions of our research itself:

H5a. Performance in Super Hexagon will decrease with age;

H5b. Performance in Super Hexagon on day 2 will be predicted by performance on day 1.

Finally, we focus on a single-player context in this paper—due to the dual benefits of both contributing an experiment with closely controlled variables, and to better situate the player experience of performance under pressure in single-player titles. To the former point, we prioritized controllability (and thus, strong internal validity and reproducibility) as this work represents an early contribution to an emerging topic of research— and thus we contribute a robust foundation on which to extend future research efforts in other contexts (such as multiplayer games, which are inherently less controllable due to human factors). However, we expect that our results could extend to multiplayer games, and certainly generate insights more broadly into the relationship between performance under pressure and player traits. To the latter point, we also contend that it is important to examine choke in single-player contexts as the single-player experience may likewise be moderated by failures in performance— especially as players seek, and are driven by, challenge in play [3, 88]. As such, it is important for stakeholders (e.g., game designers, developers, and scholars) to understand how individual variations in player traits may influence their experience of performance failure in a variety of game contexts.

3 MATERIALS AND METHODS

3.1 The Game

For the study, we used a reproduction [65] of Super Hexagon (see Figure 1), which is described as a "minimal action game" by its creator [31]. Compared to the commercial version of the game, the version in our study included additional logging features and only a single level that was based on the commercial game's first level by studying video recordings of the commercial game. The aim of the game is to survive for as long as possible as obstacles move inward from the screen's edges while rotating about a central hexagon. This clone of the game was implemented in the Unity game engine and displayed via a WebGL build on a web page. Using a clone of the game provided additional control of the experiment by ensuring that no aspect of the gameplay differed between the participants (they played an identical level

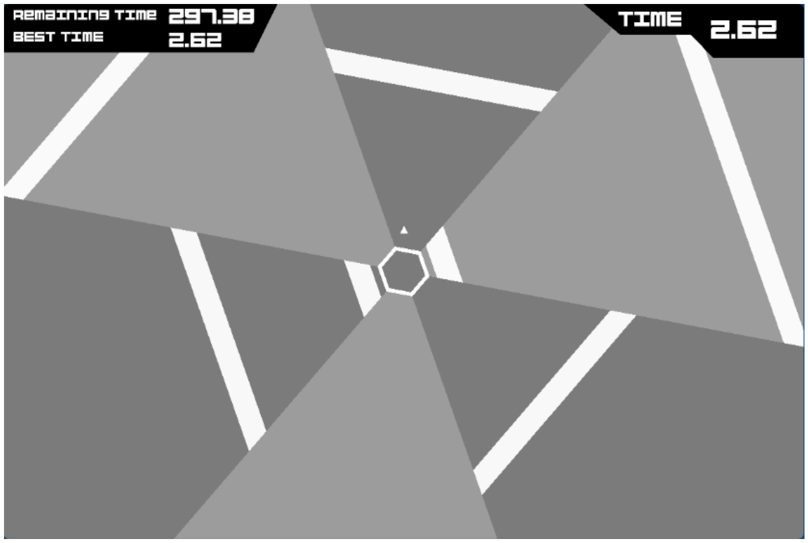

Fig. 1. A screenshot of the Super Hexagon clone used within the study. In the middle of the screen, the player's character is shown as a small triangle that rotates around the central hexagon. Obstacles move in from the edge of the screen and move toward the central hexagon.

with the same obstacles in every attempt). This provided us with ideal conditions for a controlled study with strong internal validity. The source code for our clone of the game is publicly available via GitHub[1].

Super Hexagon met our research needs in several different ways. First, because the most closely related past work explored ASO in the context of sports competition, where performing well is important, we needed a game where player performance was similarly important. We also needed a game with frequent opportunities for choking or clutching—that is, frequent potential for failure. Finally, we needed a game that would be accessible to the participants of an experiment. Super Hexagon met all of these requirements—the game is accessible to participants because it has minimal controls (only two keys) and a clear goal (avoid the obstacles), meaning it is easy for new players to learn how to play and start playing right away. Its simplicity also means that performance is easy to quantify (in terms of time played until failure), and it is important to avoid failure because doing so is directly linked to how much progress is made in the game. Super Hexagon is particularly well suited to experiments because performance differences over time are easy to identify; the game is difficult for new players who can fail to get past even the first few obstacles. In other words, it requires players to learn a skill where there are clear differences between experts and novices [44, 60] and player performance can improve over a long time [44, 104]. This is similar to the types of skills players develop within more complex games—the execution of which might be affected by choke or clutch moments. Finally, Super Hexagon has been successfully used in the past to explore player performance in games [66].

3.2 Stress Induction

Participants who were assigned to complete the stress induction task before the game spent five minutes on our custom implementation of the computerized paced auditory serial addition task (PASAT-C), described by [86] (shown in Figure 3). The task involves participants adding together the two digits shown, and then clicking the button with the correct

[1] https://github.com/colbyj/SuperHexagonClone/

Fig. 2. The bubble-popping "game" used for participants not undergoing stress induction. Circles representing bubbles slowly appeared on-screen and as participants clicked on them they would "pop" into a collection of smaller circles.

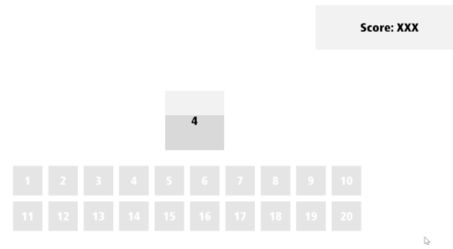

Fig. 3. The PASAT-C stress induction task used within the study. The player's current score was shown in the top-right and the present number in the centre. The possible selections for the sum of the past two numbers were shown as two rows of buttons at the bottom.

sum. Then another digit will be shown, and the participant will need to ignore the sum and instead recall the last digit shown before the current digit and mentally calculate a new sum. Our version of the task starts with digits being presented 3 seconds apart. Over the five minutes, the time between digits gradually decreases to 1.5 seconds. Our implementation of the task was done with the Unity game engine and was presented to participants via a WebGL build on a web page.

For participants not undergoing stress induction, we presented them with a simple task where they were supposed to click circles representing bubbles on the screen to make them "pop" (see Figure 2). One circle was added to the screen every second, and if not popped, each stayed visible on-screen for five seconds before fading out. The effect of both tasks on state stress was evaluated via a pre-study. This task was implemented in Javascript using the p5.js[2] library and presented to participants on a web page.

3.3 Measures of Individual Differences

Reinvestment Scale (RS) [91]: This 20-item scale measures predisposition towards "reinvesment", or the tendency to direct one's attention towards one's own movements when under stress. High reinvestors are thought to perform worse under stress than low reinvestors. The scale includes questions relating to rehearsal (e.g., "I remember things that upset me or make me angry for a long time afterwards."), private self-consciousness (e.g., "I reflect about myself a lot."), public self-consciousness (e.g., "I'm concerned about the way I present myself."), and cognitive failures (e.g., "Do you have trouble making up your mind?"). It results in one value representing a predisposition towards reinvestment. In line with past work [15], we used a 5-point Likert scale ranging from "extremely uncharacteristic" to "extremely characteristic".

Action Control Scale (ACS-90) [81]: This 24-item scale measures whether an individual is more action-oriented or state-oriented. The scale presents concrete situations and requires one to choose between two specific responses relating to either action orientation or state orientation. It includes two sub-scales (*demand-related* and *failure-related ASO*, each 12 items). The failure-related sub-scale measures action orientation subsequent to failure in contrast to state-oriented preoccupation (e.g., *"When I am told that my work has been completely unsatisfactory..."* with the action-oriented option, *"I don't let it bother me for too long."* and the state-oriented option, *"I feel paralyzed."*). The other sub-scale measures

[2]https://p5js.org/

demand-related action orientation compared to hesitation (e.g., *"When I have to solve a difficult problem..."* with the action option, *"I usually get on it right away."*, and state option, *"Other things go through my mind before I can get down to working on the problem."*). The number of times an action-oriented option was chosen is summed up for each sub-scale, which results in an ASO score ranging from 0-12.

Attentional Control Scale (ACS) [38]: This 20-item scale measures one's ability to direct one's attention intentionally in terms of control over focusing and shifting attention [38, 70]. For example, "When a distracting thought comes to mind, it is easy for me to shift my attention away from it." The scale uses a four-point Likert scale from "almost never" to "always." Considering that performance drops under pressure relate to shifts in attention, we thought that attentional control would be related to in-game performance.

3.4 Measures of Subjective Responses to Experimental Tasks

Challenge Originating from Recent Gameplay Interaction Scale (CORGIS) [37]: This 30-item scale measures different types of challenge that a player faced during a recent gaming experience. For our study, we used the cognitive challenge subscale, which relates to challenges involving memory, observation, and problem-solving capabilities (e.g., "I had to think several steps ahead when playing the game."), and the performative challenge subscale, which relates to challenges involving reaction time, precision, and accuracy (e.g., "Quickly responding to things that I saw was an important part of the game."). The scale uses a seven-point Likert scale from "strongly disagree" to "strongly agree".

Self-Assessment Manikin (SAM) [23]: This assessment tool provides a non-verbal seven-point pictorial assessment of one's current arousal, valance, and dominance. As we have no specific hypotheses or research questions related to valance or dominance, we report on arousal only.

Visual Analogue Scale (VAS) [29, 125]: This 8-item scale consists of questions to evaluate a participant's present subjective stress. Each question is presented as a slider from 0 to 100 (e.g., "How tense are you at this moment?").

3.5 Measures of In-Game Performance

We had three measures of in-game performance for Super Hexagon. All three measures are in seconds.

Average time alive: Participants played as many rounds as possible within five minutes of play. Performance was therefore quantified in terms of how long players were able to stay alive on average for a round of play, in seconds. Because the last round was always interrupted by the time running out it was omitted from the calculation, as were any rounds in which the participant did not attempt to play (no keys were pressed).

Maximum time alive: Participants may have had one round in which they performed particularly well. Therefore, we used the time of this attempt as a measure of performance within the game.

Stalled progress time: Participants may not have made consistent progress at improving at the game, and this is represented by the length of time in seconds that they failed to make progress in improving their score. This measure of performance was inspired by [67] and was calculated by iterating through each of a player's attempts and working out the player's current high score for a given attempt. If the attempt being considered did not result in a higher high score or a tied high score, then that attempt's time was added to the variable. A player who continued to improve at every attempt would have a stalled progress time of 0 seconds.

4 PRE-STUDY

We conducted a pre-study to evaluate our chosen stress induction technique.

4.1 Procedure

The study was presented over the internet via a custom website created using a web-based experiment creation framework [64]. All tasks and questionnaires were presented to participants within their web browser on their personal computers.

Participants completed a demographics questionnaire and then completed the VAS. Participants were then randomly assigned to complete either the PASAT-C task or bubble popping task for five minutes. After, participants completed the VAS again.

4.2 Recruitment

We recruited participants from Prolific (www.prolific.com), an online platform designed to connect researchers with research participants. Prolific was used for the pre-study and full study as it allows for the recruitment of a large number of high-quality participants; previous work has found that participant data from Prolific is of higher quality than data from Amazon's Mechanical Turk, Qualtrics, or a sample of undergraduate students [39]. Participants were recruited from the USA and we specified that participants must have 3 or more hours playing videogames per week on average (to align with the study itself). Participants were paid £1.20 for 8 minutes of their time. A total of 85 participants completed the pre-study (average age of 34 years, SD=10, min=19, max=64; 46 men, 35 women, 4 "prefer not to disclose"). 43 participants were assigned to complete the bubble-popping game and 42 were assigned to complete the PASAT-C.

4.3 Analyses and Results

We computed an ANCOVA (analysis of variance) using VAS score after the task as a dependent variable and condition (PASAT-C or bubble-popping game) as a between-subjects factor. The VAS score before the task was used as a covariate due to this approach resulting in more statistical power over a change from baseline or a repeated-measures ANOVA [25]. Alpha was set at .05.

We found a significant main effect of condition on VAS score ($F_{1,82} = 18.94$, $p < .001$, $\eta_p^2 = .188$). Participants rated their present subjective stress as higher after the PASAT-C than after the bubble-popping game (see Figure 4).

Fig. 4. Chart showing the descriptive means for the VAS measurements before and after the task. Error bars are 95% confidence intervals.

5 STUDY

5.1 Procedure

The study was presented over the internet via a custom website created using a web-based experiment creation framework [64]. All tasks and questionnaires were presented to participants within their web browser on their personal computers.

A diagram showing the procedure of the experiment is shown in Figure 5. Participants completed the study over two days. On the first day, participants responded to questionnaires and played a 5-minute baseline session of a reproduction of the commercial game, Super Hexagon. All participants were then assigned to one of two conditions: one where they completed a stress induction task, and another where they completed a simple bubble-popping task. The next day, participants were invited back to complete more questionnaires, complete their assigned task, and play a test session of our version of Super Hexagon. The study received approval from the Behavioural Research Ethics Board at the University of Saskatchewan.

5.2 Recruitment

Like the pre-study, we recruited participants from Prolific, using the same search criteria as the pre-study, except that they were also excluded from participating if they had completed the pre-study and therefore were not familiar with the bubble-popping game or the PASAT-C. For the first day of the study, participants were paid £1.35 for 9 minutes of their time and on the second day, £3.90 for 25 minutes of their time. A total of 185 participants completed both days of the study. We filtered out 13 due to having a low framerate (<30 frames per second) while playing Super Hexagon, which would have made it difficult to play the game successfully. An additional two participants were filtered out due to not responding to attention checks placed within the questionnaires. We filtered out an additional 27 participants who had more than 5 attempts at Super Hexagon where they did not attempt to play the game (no inputs were made). This left us with 144 participants (average age of 34.5 years, SD=9.45, min=19, max=70; 94 men, 47 women, 3 non-binary). There were 75 participants who completed the PASAT-C task and 69 completed the bubble-popping task. We ensured that participants were engaging with their assigned task by checking their logged scores.

We chose to not recruit participants based on Super Hexagon expertise, but instead ensure that expertise was evenly distributed between the two groups. This was done by sorting participants based on their performance on Day 1 and alternately assigning participants to each condition. Because not every participant returned (and some were filtered out), we confirmed that skill was similar between the groups by checking day 1 performance and challenge (i.e., prior to the stress induction). An independent-samples t-test showed no differences in day 1's average time alive

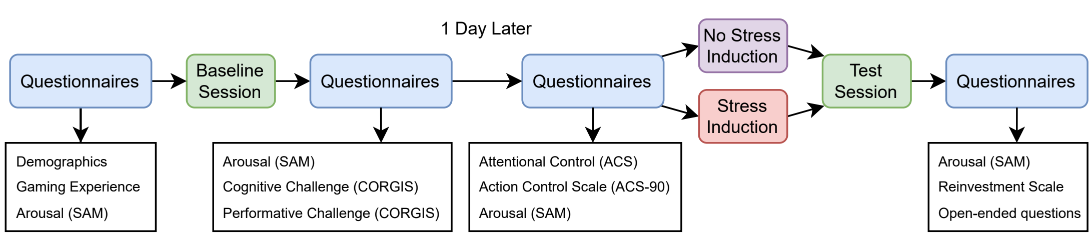

Fig. 5. Overview of the procedure of the study. Under each questionnaire block, the specific questionnaires and their ordering in the study is shown.

($t(142) = .538, p = .591$), CORGIS-C ($t(142) = .702, p = .484$), or CORGIS-P ($t(142) = .448, p = .655$); see Table 1 for descriptive statistics.

5.3 Analyses

5.3.1 Quantitative Analyses. We conducted twelve moderated regressions to investigate the relationships between trait reinvestment and action-state orientation and performance measures, depending on condition. Specifically, we used Process 4.3 for SPSS [55], with X = trait (reinvestment, failure-related action-state orientation, demand-related action state orientation, or attentional control), Y = performance (average time alive, maximum time alive, or stalled time), W (moderator) = stress condition, and using the covariates of age, performative challenge, and the day 1 value of the performance measure used as Y. In terms of the co-variates, we included performative challenge as it indicates how challenging they found the game in terms of reaction time, precision, and accuracy, which are the core game mechanics in Super Hexagon. We included age, as we expected that performance would decrease with age— regardless of stress or action-state orientation—given that a strong performance in Super Hexagon depends heavily on reaction time, which decreases with age [113]. We included day 1 performance as a covariate so that day 2 performance measures were indicative of *performance relative to their individual base skill level*, as this is more indicative of performance under pressure (e.g., choking, tilting) than simply looking at differences in individual level of skill. With these models, we expect a strong association between day 1 performance and day 2 performance in each model. We do not expect to see main effects of traits on performance (as it would reflect a performance differential from day 1). It is possible that stress condition could directly affect performance, which would reflect a decline or improvement from day 1 performance, based on the stress condition. However, our assumption (based on related work; see Section 2), is that participants are likely differentially affected by the stress condition based on their personality traits (and action-state orientation in particular). Therefore, more importantly than the main effects, we expect to see a significant interaction effect between stress condition and trait on performance, if the trait is relevant to performance under pressure. We checked for general influences of arousal on performance on day 2 (controlling for day 1's performance) with three Pearson correlations. Arousal represents intraindividual differences rather than interindividual differences, but since arousal is a relevant influence to performance, and we aim to give an overview of several possible influences on choking, we included it for completeness.

5.3.2 Qualitative Analyses. We conducted an inductive thematic analysis based on the procedure outlined by Braun and Clarke [24]. Participants were asked two open-ended questions relating to the study ("Reflecting on your recent play session, did you experience any times when you felt you performed worse than you believed you were capable of and made a mistake? If so, can you describe what sort of mistakes you think you made?" and "Do you have any comments about the study?"). The responses to the two questions were combined for the analysis and were coded by the first author, who identified features within the responses that could be considered the most basic elements within the response [22, 24]. The objective of the analysis was to explore the variety of unique ways that players explain the mistakes they made within the game.

Working through the data, if a new feature was identified, then a new code was created, otherwise an existing code was associated with the response. Responses could have multiple codes associated with them. The codes were then grouped together based on whether they described similar or related concepts and were associated with themes. Codes were only assigned to a single theme. The set of candidate themes and their associated codes were then reviewed by the other authors, upon which they were finalized after a discussion. Further, the associations between the codes and the responses were cross-checked by the other authors of the paper.

5.3.3 Positionality Statement. All authors of this paper have a background in games user research and have published work previously in the context of player performance in games. The first author has played over 24 hours of Super Hexagon since 2012 and developed the clone of the game by closely studying the patterns within the game and the mechanics of the game. All other authors have played Super Hexagon casually in the past.

Table 1. Descriptive statistics of traits, performance, and experienced challenge split by stress condition. Higher values indicate more of the construct (e.g., more reinvestment) and higher values for action-state orientation (fASO and dASO) indicate greater action orientation.

	Stress (PASAT-C)					**No Stress (Bubbles)**				
	N	Min	Max	Mean	SD	N	Min	Max	Mean	SD
Reinvestment	75	1.20	4.65	3.31	0.74	69	1.85	4.50	3.27	0.59
fASO	75	1.00	11.00	5.27	3.13	69	1.00	11.00	5.44	2.90
dASO	75	1.00	11.00	6.28	3.53	69	0.00	11.00	6.28	3.41
Attentional Control	75	1.70	3.85	2.74	0.48	69	1.15	4.00	2.65	0.56
Average Time Alive (Day 1)	75	3.50	27.97	10.16	4.24	69	3.45	24.33	10.53	3.97
Average Time Alive (Day 2)	75	3.55	31.27	13.67	5.67	69	4.92	27.15	14.02	5.32
Maximum Time Alive (Day 1)	75	5.94	50.72	17.51	6.29	69	4.81	40.36	18.70	6.69
Maximum Time Alive (Day 2)	75	5.89	43.32	21.47	7.27	69	10.39	63.19	22.40	8.23
Stalled Time (Day 1)	75	87.03	231.16	150.22	27.62	69	92.04	213.87	153.35	24.52
Stalled Time (Day 2)	75	118.51	235.04	172.20	25.49	69	116.05	218.98	177.19	22.64
Arousal (Day 1, Before)	75	1.00	6.00	2.98	1.24	69	1.00	6.00	3.01	1.13
Arousal (Day 1, After)	75	1.00	7.00	4.44	1.42	69	1.00	7.00	4.74	1.43
Arousal (Day 2, Before)	75	1.00	6.00	3.17	1.25	69	1.00	6.00	3.19	1.37
Arousal (Day 2, After)	75	1.00	6.00	4.52	1.31	69	1.00	7.00	4.61	1.47
CORGIS-C	75	3.36	7.00	5.39	0.84	69	3.00	7.00	5.49	0.86
CORGIS-P	75	4.80	7.00	6.58	0.55	69	5.20	7.00	6.61	0.47

5.4 Results

Descriptive results for the traits, performance, and their experienced challenge of Super Hexagon are shown in Table 1.

5.4.1 Arousal and Performance. We performed a check to see whether the Yerkes-Dodson Law applies to our data. To test for the non-linear relationship (inverted U-shape), we transformed the data. Arousal was measured on a scale from 1 to 7, so 4 should represent the optimal medium arousal. The further away from this mid-point, the more detrimental to the performance the arousal should be. Therefore, values of 5 were recoded to be equal to 3, 6 was equal to 2 and 7 was recoded to 1. Correlation analyses show that the closer the arousal was to a medium level of arousal on day 2, the longer the average time alive (r = .219, p = .004). Maximum duration was not significantly positively correlated with a medium arousal, however, the relationship was marginal (r = .130, p = .061) with a tendency towards a better performance when arousal was medium. On the other hand, stalled time was longer when the arousal was medium (r = .150, p = .037). This indicates that on average, medium arousal had a positive effect on performance but that performance improvement over time was inconsistent.

5.4.2 Moderated Regressions. Results of the moderated regressions are shown in Table 2. In all models, performance on day 2 was predicted by performance on day 1, confirming H5a. Additionally, age explained a significant amount of variance, in line with our expectations—as performance in Super Hexagon relies on reaction time, which decreases with age [113], we observe that increases in age are negatively associated with all three performance measures in all models, confirming H5b.

Table 2. Moderated regression results with explained variance at each level, regression coefficients (b), standard error (SE), and *p*-values for regressions predicting performance measures (average time alive, maximum time alive, stalled time), using traits (reinvestment, failure-related action-state orientation (fASO), demand-related action state orientation (dASO), or attentional control (ACS)), and moderated by stress condition. Covariates included age, performative challenge (CORGIS-P), and the day 1 value of the performance measure.

		Average Time Alive			**Max Time Alive**			**Stalled Time**		
		b	SE	p	b	SE	p	b	SE	p
Reinvestment	*First-Day Performance*	**1.110**	**.059**	**<.001**	**.878**	**.065**	**<.001**	.149	.077	.056
	Age	**-.072**	**.026**	**.006**	**-.126**	**.045**	**.006**	**-.447**	**.213**	**.038**
	CORGIS-P	.157	.434	.719	.736	.762	.336	6.542	3.888	.095
	Reinvestment	-.020	.343	.954	-.173	.606	.775	.857	3.090	.782
	Stress Condition	-.449	1.117	.689	.193	1.977	.923	-10.789	10.135	.289
	Reinvestment x Stress	.142	.334	.672	-.046	.591	.938	2.596	3.034	.394
fASO	*First-Day Performance*	**1.114**	**.058**	**<.001**	**.874**	**.065**	**<.001**	**.162**	**.076**	**.035**
	Age	**-.073**	**.025**	**.004**	**-.127**	**.044**	**.005**	**-.454**	**.208**	**.031**
	CORGIS-P	.269	.429	.531	.731	.761	.339	5.831	3.841	.131
	fASO	-.069	.072	.341	.139	.129	.284	.720	.651	.271
	Stress Condition	-.753	.442	.091	.176	.791	.825	5.410	4.011	.180
	fASO x Stress	**.143**	**.072**	**.049**	-.024	.130	.853	**-1.418**	**.656**	**.032**
dASO	*First-Day Performance*	**1.110**	**.058**	**<.001**	**.881**	**.065**	**<.001**	**.156**	**.079**	**.050**
	Age	**-.071**	**.026**	**.007**	**-.129**	**.045**	**.005**	**-.480**	**.214**	**.026**
	CORGIS-P	.158	.429	.713	.705	.752	.350	6.940	3.845	.073
	dASO	-.016	.064	.802	.090	.113	.428	.027	.594	.964
	Stress Condition	-.263	.450	.559	-.183	.796	.819	2.353	4.106	.568
	dASO x Stress	.045	.063	.478	.035	.111	.753	-.731	.573	.204
ACS	*First-Day Performance*	**1.110**	**.059**	**<.001**	**.881**	**.065**	**<.001**	.143	.078	.069
	Age	**-.072**	**.025**	**.005**	**-.124**	**.044**	**.006**	**-.470**	**.211**	**.027**
	CORGIS-P	.157	.430	.715	.668	.751	.375	7.015	3.852	.071
	ACS	-.020	.422	.963	.840	.740	.259	-2.896	3.850	.453
	Stress Condition	-.335	1.157	.772	-1.046	2.035	.608	7.125	10.494	.498
	ACS x Stress	.131	.421	.756	.388	.741	.601	-3.431	3.814	.370

Failure-Related Action-State Orientation. The models for *fASO* for each performance measure were significant, driven heavily by performance on day 1, as expected: average time alive ($R^2 = .786, F(6, 137) = 83.901, p < .001$), maximum time alive ($R^2 = .666, F(6, 137) = 45.463, p < .001$), stalled time ($R^2 = .101, F(6, 137) = 2.556, p = .022$). There was a significant interaction between stress condition and fASO on average time alive ($p = .049$) and stalled time ($p = .032$), but not for maximum time alive ($p = .853$), partially confirming H1. See Figure 6 for a visualization of the interactions.

Demand-Related Action-State Orientation. The models for *dASO* were also significant for each dependent measure: average time alive ($R^2 = .787, F(6, 137) = 84.243, p < .001$), maximum time alive ($R^2 = .664, F(6, 137) = 45.137, p < .001$), stalled time ($R^2 = .103, F(6, 137) = 2.627, p = .019$). However, in all cases, there was no significant association between dASO and performance, no significant direct effect of stress condition, and no interaction between stress condition and dASO on performance. Thus, we do not provide empirical support for H2. See Figure 6.

Reinvestment. The models for *reinvestment* were significant for each dependent measure: average time alive (R^2 = .786, $F(6, 137) = 86.963, p < .001$), maximum time alive ($R^2 = .665, F(6, 137) = 45.325, p < .001$), stalled time ($R^2 = .099, F(6, 137) = 2.508, p = .025$). However, in all cases, there was no significant association between trait reinvestment and performance, no significant direct effect of stress condition, and no interaction between stress condition and reinvestment on performance. The significant model was driven primarily by the strong association between day 1 performance and day 2 performance for a participant. Thus, we do not provide empirical support for H3.

Attentional Control. The models for *attentional control* were also significant for each dependent measure: average time alive ($R^2 = .786, F(6, 137) = 83.901, p < .001$), maximum time alive ($R^2 = .666, F(6, 137) = 45.463, p < .001$), stalled time ($R^2 = .101, F(6, 137) = 2.556, p = .022$). However, in all cases, there was no significant association between attentional control and performance, no significant direct effect of stress condition, and no interaction between stress condition and attentional control on performance. The significant model was again driven primarily by the strong

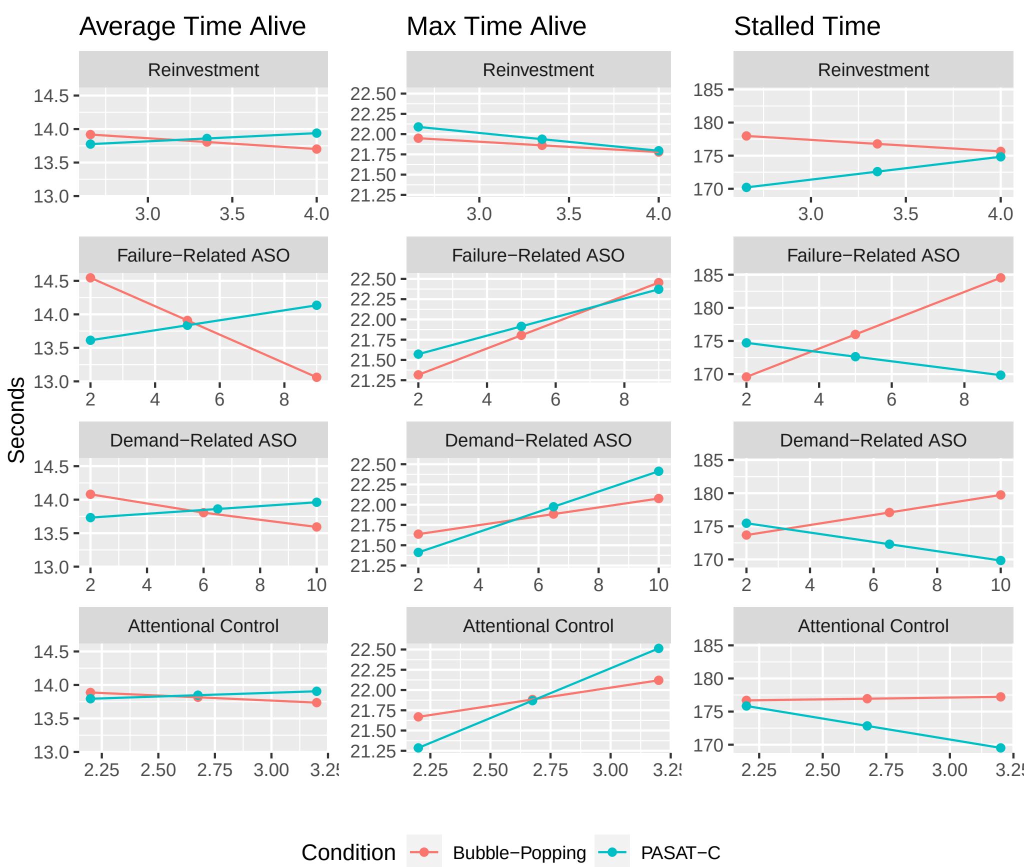

Fig. 6. A visual representation of the conditional effects of stress (W) on the relationship between traits ((X): Reinvestment, fASO, dASO, and Attentional Control) and performance ((Y): Average Time Alive, Maximum Time Alive, Stalled Time). Data are plotted at low, medium, and high levels of the trait, based on statistical characteristics of the sample distribution [55]

association between day 1 performance and day 2 performance for a participant. Thus, we do not provide empirical support for H4.

5.4.3 Qualitative Results. Results of the thematic analysis are presented by theme. Of all the responses received, 19 did not talk about Super Hexagon, and 14 made no comment. We identified themes relating to choosing in-game actions to make, difficulties in moving and positioning one's character, directing attention or focus, and comments about the game's design. We also received responses relating to how performance was affected by physical or mental state, or that performing worse than expected was due to inexperience. One theme was related to how one's performance in past trials led to decreases in performance in subsequent trials. Some participants felt that their performance was affected by not having memorized the patterns shown rather than having trouble making decisions or executing movements. Finally, two participants noted that they simply had little interest in the game and that led to their performance not matching what they believed they were capable of. Refer to Table 3 for detailed results.

On top of this, despite our question, we found that many participants responded that they were satisfied with how they had done in the game, feeling that they performed in line with their capabilities (even if they acknowledged that they may not have performed well). For example, *"I think I performed about what I was capable of. The game was very fun, and I felt that I got a little better over the course of the short play time."* (P36, Man, 26). 22 participants commented that they were satisfied with their performance in some way.

6 DISCUSSION

In this paper, we set out to better understand the reasons for the propensity to choke or clutch under pressure and begin to integrate several theoretical concepts that have been suggested to contribute to performance differences under demanding conditions. We provide an overview of different concepts and highlight the potential of considering action-state orientation, a theoretical construct that has been successfully applied to explain performance differences under pressure in sports but has not yet been adopted to the same effect in digital games.

6.1 Summary of Results

We proposed that individual differences in self-regulatory ability under stress, in particular, failure-related action-state orientation would be at the root of propensity to choke and this is indeed what we found. Via twelve moderated regression analyses, we observed a significant interaction between fASO and stress condition for two performance measures: average time alive and stalled progress time, partially validating H1. When stressed (i.e., after undergoing the PASAT-C stress induction), action-oriented players performed better relative to their baseline but when not intentionally stressed (i.e., after playing the bubble-popping condition), state-oriented players performed better relative to their baseline. We found no significant differences relating to any other trait measure (dASO, reinvestment, and attentional control), providing no evidence for H2–H4.

Our qualitative analyses revealed various reasons why a player's performance failed to live up to their expectations. Many responses focused on the things players were doing or attempting to do within the game (choosing actions, carrying out movement, attention shifts, memorization), others focused on the game itself (game design), and the rest focused on the player's own state (physical state, mental state, inexperience, performance as a catalyst and low motivation). We explain how these themes relate to our trait measures in the next section.

Table 3. A table summarizing the stated reasons players believed they played worse than expected. Shown are themes, sub-themes, a count of the number of participants that had responses relating to that sub-theme, and an example response for each sub-theme. Percentages shown are based on the number of participants who gave a relevant response (i.e., not a blank response, an unrelated response, or a statement that they were satisfied with their performance, N=109). All quotes include participant numbers (e.g., P123), their self-identified gender (e.g., "woman"), and their age.

Theme	Sub-Theme	N	%	Example Response
Choosing Actions (N=22, 25.3%)	Confusion when choosing direction.	12	13.8%	"I'd think to go one way but rethink and try other way and get caught doing so." (P18, Man, 30, No Stress)
	Confusion about mapping buttons to directions.	5	5.7%	"Yes, a few times I pressed the wrong arrow and made the pointer move the wrong way from what I meant to do." (P171, Woman, 39, Stress)
	Sticking to one direction too much.	2	2.3%	"My tendency to prefer only moving in one direction rather than both also costed me a few runs." (P82, Man, 27, No Stress)
	Unable to make a decision.	2	2.3%	"Yes I feel like I was overthinking things and kind of froze many times not being able to really move in any direction that made sense." (P21, Woman, 33, Stress)
	Losing track of position.	1	1.1%	"There were times where I sort of lost track of my position on the screen and ran right into the oncoming wall while barely attempting to move." (P12, Man, 28, Stress)
Carrying Out Movement (N=30, 34.5%)	Trouble positioning character relative to obstacles.	26	29.9%	"I kept moving the arrow slightly too far." (P130, Woman, 28, Stress)
	Trouble with timing movements.	4	4.6%	"Yes, I thought I moved my curser at the right time, but then I realized I moved it too soon and failed the game." (P7, Woman, 44, Stress)
Attention or Focus Shift (N=16, 18.4%)	Focus should have been elsewhere.	10	11.5%	"I also became slightly too focused on the patterns of the incoming walls rather than the points I had to reach to make it through safely." (P12, Man, 28, Stress)
	Distracted from the game.	3	3.4%	"I was interrupted twice by family so had several seconds of doing nothing." (P88, Man, 25, Stress)
	Attention on own performance affected performance.	2	2.3%	"I think I was always capable of going a little farther in the game, but every time the 'new high score' phrase popped up, it threw me off and I would end up messing up shortly after." (P72, Man, 36, Stress)
	Not ready to pay attention to the game.	1	1.1%	"There were times when the marker hit a wall as soon as the timer began, and I guess I just was not ready as I thought I was." (P139, Woman, 45, No Stress)
Game Design (N=11, 12.6%)	Can't handle difficulty increases.	6	6.9%	"I kept on dying once the speed of the game started to increase." (P145, Man, 32, No Stress)
	Criticism of input modality.	2	2.3%	"I was handicapped by using the arrow keys." (P96, Man, 34, No Stress)
	Music was distracting.	2	2.3%	"...the music was making it hard so sometimes I'd fail due to just not being able to concentrate on it." (P18, Man, 30, No Stress)
	Trouble identifying threats and safe areas.	1	1.1%	"It was sometimes hard to differentiate the colors and the white color blended in some times." (P80, Man, 25, No Stress)
Mental State (N=8, 9.2%)	Frustration.	3	3.4%	"I did get a bit frustrated when I would hit a wall and didn't think I would." (P49, Woman, 28, Stress)
	Impatience.	1	1.1%	"I was trying to rush to beat my score causing my to be careless." (P79, Man, 31, Stress)
	Nervousness.	1	1.1%	"When I was nervous it made me make mistakes." (P120, Woman, 50, Stress)
	Not relying on instincts.	1	1.1%	"I made the mistake of not relying on my instincts enough." (P124, Man, 29, No Stress)
	Overconfident.	1	1.1%	"I got too confident in myself." (P142, Man, 24, Stress)
	Overthinking.	1	1.1%	"Sometimes I overthink things and that leads me to performing poorly." (P151, Man, 39, No Stress)
Physical State (N=8, 9.2%)	Dizzyness.	5	5.7%	"Super Hexagon makes me unreasonably dizzy." (P17, Man, 31, No Stress)
	Fatigue or physical issue.	2	2.3%	"I started to experience a tendonitis flare up which caused me to be more concerned with my health than my score..." (P74, Woman, 28, Stress)
	Motion sickness.	1	1.1%	"The game made me very nauseous the same as last time and gave me terrible motion sickness..." (P96, Man, 34, No Stress)
Physical State (N=8, 9.2%)	Dizzyness.	5	5.7%	"Super Hexagon makes me unreasonably dizzy." (P17, Man, 31, No Stress)
	Fatigue or physical issue.	2	2.3%	"I started to experience a tendonitis flare up which caused me to be more concerned with my health than my score..." (P74, Woman, 28, Stress)
	Motion sickness.	1	1.1%	"The game made me very nauseous the same as last time and gave me terrible motion sickness..." (P96, Man, 34, No Stress)
Inexperience (N=6, 6.9%)	Need practice.	3	3.4%	"I think I would get better with practice." (P127, Man, 70, Stress)
	Basic mistakes.	2	2.3%	"... I was frequently feeling like the mistakes I was making were dumb ... I had no excuse for messing up this time." (P134, Man, 48, No Stress)
	Strategy.	1	1.1%	"Yes, I made many mistakes, I couldn't get the strategy right." (P85, Woman, 58, Stress)
Performance as a Catalyst (N=6, 6.9%)	Mistakes led to more mistakes.	3	3.4%	"I performed worse after I made mistakes and then got myself frazzled for a minute..." (P48, Man, 35, Stress)
	Poor performance after doing well.	3	3.4%	"Yeah, I had a pretty good run this time. After ending that streak it felt hard to refocus to get a better time." (P149, Woman, 31, No Stress)
Memorization (N=5, 5.7%)	Learning the patterns or comments on memory.	5	5.7%	"I sometimes felt like I could do a better job remembering where the lines would be." (P44, Man, 44, Stress)
Low Motivation (N=2, 3.3%)	Low interest in game.	2	2.3%	"Frequently found myself thinking about how little interest I had in the game, and there was no incentive to score highly." (P29, Woman, 36, Stress)

6.2 Explanation of Results

Interestingly, traits that have previously been identified as contributors of choke did not significantly relate to performance under pressure in Super Hexagon. One possible explanation for this is that the potential avenues for failure in Super Hexagon did not align with the types of underperformance specific to these traits. An alternative possibility is that reinvestment and attentional control *do* affect performance under pressure, but given that there is so much variety in the ways that players can fail in the game, the effect is small—so our study lacked sufficient statistical power to find differences.

In contrast, we do find results for fASO—such that players higher in fASO perform better relative to their baseline when under stress, and players lower in fASO perform better without stress. We provide several possible explanations for this pattern of results below.

6.2.1 Reinvestment. As no relationship emerged between trait tendency towards reinvestment and performance under pressure, it may be that Super Hexagon does not possess the requisite complexity to invoke reinvestment. In Masters et al.'s [91] seminal work conducting and validating the 20-item Reinvestment Scale, they found that the scale did not perform in the context of a simple rod-tracing task—and suggest that this task lacked the kind of demands that would lead to reinvestment. In a follow-up study employing a more complex golf-putting task, support was found for high reinvesters (as identified by the scale) to fail under stress. As such, it is possible that Super Hexagon orients more towards the rod-tracing task (in that both require simple micro-adjustments on a single continuum) than the more complex golf-putting task.

In sports literature, reinvestment is typically studied in the context of sports with complex rulesets and varied demands (rather than simpler motor tasks) [91]. The consideration of reinvestment in digital game performance is comparatively limited—research so far has only established its usefulness in the context of competitive multiplayer videogames, and using self-report methods and not experimental work [15]. As the required inputs for Super Hexagon are limited to two keys, and correspond directionally with the character's movement, there is possibly limited opportunity for a player to revert to an earlier stage of learning under pressure—simply because this earlier stage may not exist.

Owing to the nascent adoption of reinvestment in games scholarship, it is important to make early inroads towards identifying *when* the application of reinvestment is appropriate. As such, we contend that reinvestment may be a more appropriate construct for more complex digital games. This outcome may be more pressing in digital games than in sports, as casual games—which, like Super Hexagon, involve simple mechanics and restricted inputs—represent a large contingent of the commercial games market [111]. As such, reinvestment may be more suitable for evaluations of performance in games like Dota 2 than Super Hexagon.

Responses from our participants suggest that, while reinvestment is likely not the primary reason for failures in Super Hexagon, it may still occur—albeit, less prominently—within the game. For example, some participants described an inability to map keyboard keys to a movement direction—a possible consequence of reinvestment.

6.2.2 Attentional Control. We likewise find no significant relationship between attentional control and performance under pressure in Super Hexagon. It is plausible that—owing both to the experimental design and to the pace of demands supplied by the game—there were limited opportunities for those with decreased attentional control to redirect attention elsewhere. Participants were required to play the game for a total duration of five minutes; this period may have been short enough that participants, regardless of capacity for attentional control, were able to sustain their attention. Further, despite being a mechanically simple game, Super Hexagon features a consistent and high-paced slew of task demands— during which a lapse in task attendance will result in immediate failure. This is in contrast to games intended to be played for longer durations, which often contain moments of lessened activity. For example, consider the scenario in the tactical first-person shooter Valorant where a player is defending a site and waiting for an opponent to appear— such a scenario might be more likely to invite distraction.

Just as with reinvestment, while we do not see any significant main or interaction effect that suggests attentional control to play a major role in Super Hexagon, our players did suggest that it did play at least a small role. Some players described that they found it difficult to focus, because of (for example) distracting music. Others described that being aware of their performance affected their performance, or that they were focusing on things outside of the game or the wrong aspect of the game.

6.2.3 Failure-Related Action-State Orientation (fASO). We found relationships between trait tendencies towards fASO and performance under pressure— specifically, that those higher in fASO perform better relative to their baseline when under stress, whereas those lower in fASO perform better without stress. This is in line with findings from several sports contexts, which demonstrate that state-oriented athletes do not differ from action-oriented athletes in the absence of stress [51, 79] or may even have an advantage [58], but struggle with performance under pressure or have a tendency to ruminate to their own detriment after experiencing setbacks [51, 79]. Conceptually, failure-related state orientation is the inability to end an unwanted state of negative affect [5]. Rather than accepting setbacks and moving on to the next challenge (self-relaxation or self-soothing) as action-oriented individuals tend to, state-oriented individuals are likely to be fixated on mistakes, which occupies cognitive resources and therefore, inhibits their performance [76]. These adverse effects can be mitigated by the presence of external support or social support [32, 120]; however, in this experiment no friends or support mechanisms were present.

When it comes to the qualitative results, some of the responses do relate to failure-related state orientation. In particular, "performance as catalyst", where participants shared how making a mistake led to more mistakes and "mental state", where players talked about negative affective states affecting their performance.

6.2.4 Demand-Related Action-State Orientation (dASO). We found no significant relationship between dASO and performance under pressure in Super Hexagon. However, the qualitative results also showed themes that are closely related to demand-related state orientation. This is especially true for the "choosing actions" theme. Demand-related state orientation has been shown to inhibit individuals from a decision as simple as dismissing a dialogue box during gameplay [17]. Furthermore, Super Hexagon has some similarities with a task that shows difficulty in decision-making for state-oriented individuals. The "Grid Task" [119] consists of a 24×24 grid in which participants need to move their cursor to a target square. While the cursor is moved, a second target appears and participants are instructed to move the cursor towards the closest of the two targets quickly. Unlike action-oriented individuals, state-oriented people have trouble choosing a target in those cases where both targets are equally far from the cursor [119]. In Super Hexagon, a similar hesitation might be caused whenever an obstacle could be avoided equally well by rotating either clockwise or counter-clockwise. Especially those participant comments that mentioned the inability to make such a decision could be explained by this phenomenon.

Despite the fit of demand-related action orientation to this theme, it likely just affected a small minority of participants. Rotating only in one direction, for example, is a strategy that is effective for the early parts of a trial (before the game speeds up). So sticking to one direction of rotation does not affect performance for new players who are unable to get far enough in the game for it to matter. Ultimately, Super Hexagon is not a decision-based game but rather one where failure is part of the process. As such, it is not a surprise that dASO was not a good predictor of performance in this study.

6.2.5 Arousal. Notably, while the qualitative analysis represents responses on an individual level rather than general tendencies or majority effects, it highlights how multifaceted the performance in Super Hexagon is. Many theoretical constructs could likely be combined, each representing a small share of variance. An exemption here is arousal, which also showed significant relationships with performance on a majority, rather than differential level; however, not always in the direction that was theoretically expected. Several of the participant comments can easily be interpreted as related to arousal, such as when players reported fatigue ("physical state"), nervousness ("mental state"), or low interest in the game ("low motivation"). In digital games it is common practice to introduce players to an easy level or tutorial version of a game, and then increase difficulty levels as learning occurs and performance increases [62]. Over time, as predicted by the *Wundt-curve* (which describes the relationship between arousal and hedonic value) [16], players seek out novelty and variety to avoid boredom [71]. Involvement in a game increases with task difficulty until a task is so difficult that it is no longer feasible for a player [109]. Theories of arousal, such as the Yerkes-Dodson Law [124], explain why performance can fluctuate within a player over time and why neither being tired (arousal too low) nor being stressed (arousal too high) is usually beneficial for performance. We found that players with a medium arousal level indeed performed better when it came to their average time alive in Super Hexagon. However, medium arousal appeared to be detrimental when it came to how long it took participants on average to improve. Perhaps it is more difficult to improve towards a new record when the performance is already higher to begin with. Generally, performance over time stabilizes (following a power law [95]) and it becomes more difficult to make performance gains.

6.2.6 Overall. That fASO allowed insights into performance decrements under pressure when other traits (i.e., reinvestment and attentional control) did not, suggests that fASO may be more generally relevant to performance in games—regardless of task complexity. To this end, it may be that overcoming an unwanted affective state represents a challenge more universal in gameplay than either avoiding reinvestment or managing attentional resources. While it is difficult to draw firm conclusions without also evaluating failure-related action-state orientation in additional games that vary in complexity, there are no theoretical contributions that suggest that fASO may play a reduced role in more complex tasks. On the contrary, the relevance of action-state orientation in sports contexts shows that differences in regulating emotions under stress even play a role when it comes to the motor skills in experienced athletes [51]—skills that are more complex than Super Hexagon.

6.3 Implications

Game designers have an interest in creating gaming experiences that appeal to a large number of players [35] and an understanding of how to design for differences in self-regulatory ability is of relevance. We propose that games could deliberately be designed to avoid the need to self-regulate when the game is intended for stress recovery (e.g., by reducing instances of failure) or to introduce features within the game to support players in self-regulating directly (e.g., by providing social support or optional support mechanics within the game).

One way to reduce the need to self-soothe would be to ensure that the challenge of the game is matched to a player's ability and current state via dynamic difficulty adjustment [4] or by providing additional skill assistance to reduce instances of failure [117]. However, failure does not need to be eliminated entirely. Games that lack challenge can have a worse player experience than those that are balanced [74], and even a balanced game will result in occasional failure. Beyond this, achieving success after failure can be a source of pleasure for gamers [50], so experiencing failure can be an important aspect of what eventually leads to pleasure, even for state-oriented players. Our results suggest that players who are state-oriented in terms of fASO struggle more to perform well under stressful conditions and in turn, could have a harder time achieving success after failure. Furthermore, feedback that indicates poor performance is known to further impair performance for some [34, 112]. These effects might depend on the way in which feedback after failure is presented. Game designers might therefore want to be mindful when adding feedback to games. Feedback upon failure could be presented in a positive way—for example, by highlighting how much a player improved in their recent attempt compared to past attempts, or by encouraging the player to "keep trying". This approach has been demonstrated to be beneficial in sports, by providing knowledge of results feedback only after a "good" attempt [33]. Compared to physical skills and sports, videogames also afford more opportunities for dynamic feedback on success through audiovisual feedback (e.g., audio cues tallying points earned at the end of a game, or sound and visual cues to celebrate a good attempt), real-time performance data logging (to visualise player progress), and the ability for a computer agent to interact with a player without disrupting a game. By taking advantage of the digitised form, game developers may deliberately design feedback in a way that could lessen a player's need to self-regulate.

Some state-oriented players may wish to play games that are challenging (because one's abilities do not necessarily match one's interests), so game designers could facilitate this by introducing ways to support self-regulation in their games. For example, it is possible that a state-oriented player would benefit from a mix of stressful and calm (easier) periods of play, with the calm periods potentially providing a break from constant frustration. This could partially explain why breaks are beneficial to performance in games (as in [66]). An alternative way to support self-regulation is to give players the option to ask for additional support. For example, prior work shows that providing cheat-codes can serve as an external support for state-oriented players to prevent overwhelming them while they are learning how to play a complex single-player game [120].

Game designers could also consider dynamically adjusting their games to provide additional support depending on whether the player is state-oriented. The game could measure a player's ASO (for example, covertly by asking questions through conversations with a non-player character [20] or overtly by one or more questions built into the game) and then adapt different parameters of the game (e.g., difficulty or feedback systems) or offer support to the player more frequently (e.g., cheat codes) based on their ASO.

An understanding of a player's ASO could also be relevant for game selection. For example, state-oriented players who are looking for a challenge may want to choose games that offer different types of challenges than ones based on performance [37] or where performance-related failure is less highlighted in the game. An external platform that takes into account a player's ASO (along with other psychological measures) could recommend games that are similar to a game that a player is interested in (e.g., with similar game mechanics) but more satisfying for that player due to other aspects of the game's design (e.g., how much pressure the player feels or how the player experiences failure within the game).

Finally, it may be possible to support players by helping them improve their ability to self-regulate. Past work reports that action orientation can be trained to some degree [6, 48, 49]. If a state-oriented player has a keen interest in playing games with significant performance-based challenges, then they may be better able to take on those challenges via behaviour therapy focused on acquiring action-oriented ways of dealing with anxiety-inducing situations [54] or training that focuses on shifting between low and high positive affect [48]. Training in this way might help reduce the likelihood of choking under pressure.

6.3.1 *Multiplayer Games and Esports.*

Multiplayer games provide additional opportunities to support players of differing self-regulation abilities. For team games, game designers should consider how having a variety of roles within a team can allow players to support one another. In sports, state-oriented athletes tend to prefer support roles and confine themselves to passing rather than shooting [58, 100]. Similar roles can exist in videogames—consider for example, how a player of the online shooter Team Fortress 2 can play as the medic and elevate the performance of the rest of the players on their team. State-oriented players should benefit from the presence of these roles (regardless of whether they themselves play that role) due to the social support and the experience of relatedness, which has been shown to be beneficial for state-oriented individuals under stress [32]. By adding support systems for state-oriented players to alleviate pressure and overcome failure-related rumination, these players are just as valuable to their team as action-oriented individuals.

Relatedly, while this work did not empirically evaluate choke in a competitive multiplayer context, knowledge of the influence of trait ASO on player performance may prove invaluable for esports recruitment and training. Esports contexts necessarily demand players to consistently perform at a high level in notably stressful environments—e.g., in bracketed tournaments, spectated by thousands, and in which both a player and their teammate's careers may be at stake [15]. As such, understanding players' trait ASO may enable esports personnel to create bespoke training regiments or performance constraints that accommodate for anticipated responses to stress (e.g., by coaching state-oriented players to re-focus, or encouraging teammate interactions that re-centre successes following moments of failure). One such approach might be the integration of *mental contrasting* into esports training: that is, the deliberate mental visualisation of a desired future in contrast with present realities impeding said future [40], which has been found to be effective in fostering intention enactment for both action- and state-oriented individuals [49]. As such, this work potentially contributes to a landscape of nascent research that examines the importance of integrating psychological skill use in esports research [114].

6.4 Limitations and Future Work

Our study demonstrated the value of considering action-state orientation as a theoretical lens through which to explain individual differences in game performance under stress; however, there are several limitations that should be addressed in future research. First, our choice of game was intentional, as Super Hexagon is easy to learn, but can generate repeated failures in a short time; however, our findings are limited to this particular context and should not yet be generalized to other games or genres. We did not find dASO to be a major factor to performance in Super Hexagon, but this is not surprising, since it is relevant to initiating actions and not to overcoming failure. Super Hexagon is not a decision-making game but rather a reaction time-based game. The player does not need to initiate the in-game action via a decision—instead the obstacles keep coming up until the player fails to react and needs to start over. In game genres that require players to choose swiftly between alternatives, especially with the need to weigh advantages and disadvantages, dASO would be theoretically relevant. Future work will need to investigate games with greater complexity, multiplayer games, and games in other genres. Subsequent research should also examine the relationship between performance under pressure and player experience; while choking is detrimental in a competitive setting, a temporary failure that leads to success in single-player games can be an enjoyable experience for many players [50], but potentially not all players. Furthermore, performance is not always related to enjoyment of the game, as indicated by the rise of the casual and cozy game genre. Second, we used a standard stress induction that has been used in myriad contexts, including games research [101]. This allowed us to experimentally control the type of stressor so that it was similarly experienced across participants; however, this stress induction was not directly related to the game and is not a proxy for the pressure that might be experienced due to high stakes (e.g., prize pool, tournament context) or public performance (e.g., esports, streamers). Future work should consider the role of action-state orientation in performance within these more ecologically-valid contexts of high pressure. Third, we did not have a large enough sample to explore quadratic modeling of arousal to demonstrate the U-shaped curve, and approximated it with a linear V-shaped transformation. Future work could collect a larger sample to more accurately demonstrate the role of arousal on performance.

Although there were limitations within the present study, our findings also present an opportunity for an interesting and relevant research agenda on traits that explain individual differences in performance under pressure in games. Future work can consider the role of failure and demand-related action-state orientation on game performance in contexts ranging from casual play to competitive play to high-stakes professional play. Different combinations of fASO and dASO may also predict performance in different game settings, for example, it may benefit players in specific situations to be able to down-regulate negative affect under stress (i.e., high fASO), but not require stress in order to up-regulate positive affect (i.e., low dASO). Further, understanding the role of action-state orientation on performance might pave the way for future esport training programs that personalize training to individual traits. Finally, games could also be intentionaly designed as intervention programs that help players learn to better self-regulate affect, both when under stress and when not.

7 CONCLUSION

Videogames often require players to perform under pressure, which can stem from a range of sources. Sometimes, players *choke*—perform poorly relative to their ability or *tilt*—lose control during play; however, not all players respond equivalently to pressure. Given the importance of both emotion regulation in tilting and optimal arousal in achieving optimal performance, we proposed that individual differences in ability to down-regulate negative affect under stress—known as failure-related action-state orientation (fASO)—could explain propensity to choke under pressure in gaming. Research showing the benefit of higher fASO for performing well in a variety of competitive physical sports support our exploration of this inter-individual difference in a videogaming context.

We present the results of an experiment in which we measured baseline performance in Super Hexagon (day 1), then had participants play again after being exposed to either a stress induction (i.e., PASAT-C) or a low-intensity bubble-popping game (day 2). We measured fASO, along with traits reflective of proposed explanations for choking (i.e., reinvestment, attentional control), and demand-related action-state orientation (dASO), which is the ability to up-regulate positive affect under stress. A series of moderated regressions showed that within the stress condition, (failure-related) action-oriented players performed better (relative to their baseline) in terms of average time spent alive and stalled progress, but not maximum time alive (i.e., personal best). However, in the bubble-popping condition, state-oriented players performed better on both of these measures, and there was no difference in maximum time spent alive. There was no influence of reinvestment, attentional control, or demand-related action-state orientation on performance measures. When providing reasons for their performance, participants described themes related to executing within the game, (mis)directing attention, and their own physical or mental state—justifications that cover multiple theories that explain choking under pressure.

Our results shed light on how inter-individual differences in self-regulation ability—based on a theory well-studied in motivation psychology, but rarely applied in gaming research—can provide an explanation for differences in player performance under pressure. Our findings suggest that the ability to down-regulate negative affect and overcome setbacks provides a useful theoretical lens with which gaming researchers can further explore why under pressure, some players are more likely to choke, whereas others seem to thrive.

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