ADAPTIVE BEHAVIOR IN SANDBOX GAMES: HOW MOTIVATION SHAPES USE OF AFFORDANCES IN VIRTUAL WORLDS

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ABSTRACT

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Users of video games actively interact with the game environment, impacting the contents of the environment and altering their subsequent behaviors in meaningful ways. Although motivation is essential to guide behavior, not much work has investigated how motivational processes shape in-game behavior. Therefore, this study incorporates understandings of player motivation with a concept of affordances to build a model of adaptive player behavior in games and virtual environments. The primary prediction was that threats and resources in games will shape initial motivated behaviors to explore and use affordances of the virtual world at variable rates. Using a custom-designed game with varying threats and resources available to players, the approach and avoidance behavior players exhibit in response to motivationally relevant in-game encounters was examined in a laboratory experiment. The moderating role of trait-level motivational reactivity in facilitating and inhibiting motivational responses to the game environment was also examined. A series of repeated measures ANOVAs demonstrated that players' adaptively respond to virtual environment affordances to gain benefits and avoid threats, evidenced by facilitated approach behaviors in the absence of threat as well as facilitated avoidance behaviors under threatening circumstances. Furthermore, individual differences in appetitive and defensive trait motivational reactivity moderated these effects in significant fashion. Overall, these findings clarify the role of game mechanics and affordances of the virtual environment as key shapers of user behavior, and demonstrate that gameplay is made up of discrete adaptive behaviors guided by motivated responses to the game environment.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

Video games are "lean forward media" because their content consists of the player's active engagement with the offerings of the virtual world (Jansz, 2005, p. 222). Video game players inherently have a great control over the game environment including avatars, virtual objects, and virtual agents. As the game unfolds, player actions impact the game world in meaningful ways, for example by gaining new resources or deleting presented threats, which in turn alters players' successive actions. Not only do video games allow players to change their contents, games are designed to encourage or discourage specific behaviors based on in-game features and player goals (Eden, Ewoldsen, J. Lee, Beyea, 2018; Gee, 2008). Actions and behaviors in video games are bounded by game mechanics that define and constrain users' actions in the virtual world (Sicart, 2008; Sherry, 2014). These game mechanics may guide users' motivational systems to react in certain ways, such as to collect specific objects or to defeat an enemy. In other words, the mechanics and structure of the virtual environment constrain users' action capabilities to a certain extent, such that user behavior is not entirely random or unpredictable, and can be reduced to or chunked into a predictable number of patterns based on possible actions (e.g., Weber, Behr, Tamborini, Ritterfeld & Mathiak, 2009).

Media scholars agree that gameplay is *adaptive* as users learn their possibilities and constraints via exploration of the game mechanics and develop their own ways to play to fulfill internal goals (Duncan, 2011). Learning and preference toward certain game affordances can be observed from when and how often an individual engages in specific types of behavior (A. Lang et al., 2018). However, how players learn and realize those possibilities and constraints in a specific game environment is still unclear. Therefore, the primary interest of this study is to determine how players develop in-game behaviors through their interaction with specific features of the virtual world in two ways.

First, I test the role of motivationally relevant (appetitive or aversive) information in shaping player in-game behaviors in terms of basic approach and avoidance responses to in-game environmental features. Specifically, when players enter a novel game world, their initial exploration will be guided by approach toward potential opportunities and aversion to threats in the environment. These exploratory actions are shaped by game affordances, referring to what an environment or situation allows users to do (Gaver, 1991; J. Gibson, 1979). The second goal of this study is to investigate the role of individual motivational traits in facilitation and inhibition of approach and avoidance behavior in response to these affordances. Past work has indicated that individual differences in the sensitivity to appetitive and aversive information can lead to differential behavioral and physiological reactions to motivationally relevant information or events (Carver & White, 1994; A. Lang, Kurita, Rubenking, & Potter, 2011). In the game context, for example, higher sensitivity to resource-based environmental cues may bias behavior towards approaching resources, even in the face of threat, compared to individuals with lower sensitivity. Yet, few studies to date have examined the intersection of motivational relevance and in-game affordances together as applied to video game behaviors.

Taken together, basic predictions include that (1) resource-based objects, events, and possibilities in the game will facilitate approach toward active exploration, whereas (2) threat-based features in the game will inhibit these behaviors and (3) facilitate avoidance or defensive reactions. Furthermore, I predicted that users' trait motivational reactivity will modulate the rate of facilitation and inhibition in approach and avoidance behaviors.

In order to test these predictions, I used a custom game environment which varied the level of threat (enemies) and resources (building materials and food items) available to players to induce various motivational states. The game stimulus was developed based on a sandbox exploratory game (Minecraft; Mojang, 2011) which focuses on player goals for survival, creating, and building by mining resources in the environment. The game stimulus integrated an automated data collection tool to track all user behaviors, including timestamps and spatial coordinates data to allow investigation of overtime in-game behavioral traces (Renaud & Gray, 2004; Sifa, Drachen & Bauckhage, 2018).

In this paper I first outline literature connecting the frameworks from approach and avoidance motivation (Deci & Ryan, 1985) and J. Gibson's (1979) ecological perception perspective to game behavior. I then present a framework for understanding in-game behavior based on motivational processing of in-game features. Next, I introduce an experiment manipulating the game environment in a sandbox game and the subsequent effects on player behavior. Results are discussed in terms of the role of motivational relevance on learning in-game affordances.

LITERATURE REVIEW

Motivational Perspectives on Game Behavior

Motivation can be defined as a force that gives behavior its orientation and energy (Deci & Ryan, 1985; Elliot, 2006). Motivation serves a central role in guiding actions to explore, learn, and develop individual behavioral patterns. Scholars have identified motivational functions in multiple levels of behaviors and time scales, including automatic activation induced by environmental stimuli (e.g., food, sex, danger; P. Lang, 1995), learned motivation through experiencing rewards and incentives, and proactive motivation pursued by the individual (e.g., intrinsic motivation, achievement goal; Reeve & W. Lee, 2019). While automatic motivational activation occurs immediately and unconsciously at around 50 milliseconds level (P. Lang, 1995), learned and proactive behaviors tend to be conscious and involve a subjective appraisal of a situation (W. Lee & Reeve, 2013). Recent approaches suggest considering how multiple time scales of behaviors are hierarchically related to understand how human behavior is organized through these motivational processes in multiple levels, producing more complex behaviors in the higher level (Berthenthal, 2007; A. Lang, 2014).

This paper applies this holistic perspective on motivation to understanding the development of behavior in video games. Virtual environments in video games are structured to both afford (i.e., allow) and constrain various actions (Eden et al., 2018; Gee, 2008; Sicart, 2014). Players interact with those possibilities and constraints in different trajectories (A. Lang et al, 2018; Weber et al., 2009). Therefore, it is important to consider user motivation as a state that develops, evolves, and changes through actions within the environment rather than as a fixed characteristic. However, previous studies on player motivation have focused on identifying motivational typologies for gamers, such as Bartle's (2004) player taxonomy that consists of achievers, socializers, explorers, and killers.

While varying in terms of components, different player typologies commonly identify discrete motivations such as physiological experiences (e.g., arousal), psychological experiences (e.g., immersion), social interactions (e.g., collaboration, relationship), and achievements (e.g., challenge, competition; Sherry, Greenberg, Lucas, & Lachlan, 2006; Yee, 2006). Although these typologies are useful for understanding players' preference toward a specific game genre, they do not incorporate changing properties within a game, and often assume that a player constantly pursues the same category of motivation. Yet, players may pursue different motivations in the same environment, and their motivations may change over time. For example, player goals during initial exploration of the novel game may be different from their goals after achieving the mastery of the controls or rules in the game.

Ryan, Rigby, and Przybylski (2006) suggested self-determination theory (SDT) as an alternate theory-grounded approach to player motivation. According to SDT, motivations can be internally (intrinsically) or externally (extrinsically) driven (Deci & Ryan, 1985; Ryan & Deci, 2000). Intrinsic motivation refers to an activity which is inherently interesting or enjoyable to the individual, whereas extrinsic motivation refers to doing something for an external reward such as money or praise. Yet, SDT studies on player motivation tend to focus on general experiences from a game or episode of gameplay as a whole, overlooking the actual behavioral interaction between the individual and specific elements of the game environment. Relatively little is known about motivational directions underlying numerous behaviors performed throughout the play and the energy, variability, or strength of those behaviors, even though the concept of motivation is closely tied to those aspects.

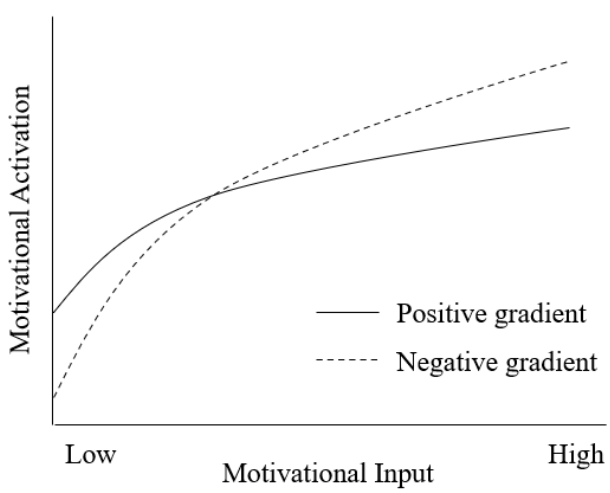
Approach and Avoidance Motivation in Game Behavior

A nuanced way to study motivation in games is by understanding motivated behavior as adaptive responses of an individual, who perceives and reacts to the environment using their evolved sensory and behavioral systems. At the fundamental level, the biological mechanism for approach and avoidance is activation in the appetitive and aversive (defensive) motivational systems that have evolved for an organism to adaptively behave to survive, defending against threat and securing resources (Cacioppo, Bernston, Norris & Gollan, 2011). Appetitive system activation organizes behaviors to approach toward positive or desired events and possibilities (e.g., rewards, resources), whereas aversive system activation organizes behaviors to avoid negative or undesirable events and possibilities (e.g., punishments, threats). Indicators of motivational activation identified by research include automatic orienting, startle responses, and neurophysiological activation to opportunities or threat-relevant stimuli (Graham, 1979; P. J. Lang, Bradley, & Cuthbert, 1990; Hayes, Duncan, Xu, & Northoff, 2014). A large body of literature has identified operation of the approach-avoidance distinction in various levels of human cognition and action, including automatic reflexes and sympathetic arousal (P. Lang et al., 1990), attention allocation and information intake (A. Lang, 2006), and directional actions toward or away from high-level goals (e.g., seeking achievement and avoiding failure; Elliot, 2006).

According to the evaluative space model (ESM), these motivational systems also exhibit differential gradients of appetitive and aversive activation as a function of motivational direction (valence) and intensity (arousal; Cacioppo et al, 2011). In a neutral or slightly positive environment, the appetitive system is slightly more activated than the aversive system (i.e., the *positivity offset*). With negative information or threat in the environment, the aversive system activates more quickly and strongly than the appetitive system reacting to positive stimuli (i.e., *the negativity bias*). Accordingly, the intercept for the appetitive activation function is higher than the intercept for the aversive activation function at the zero-to-lower level of positive input; on the other hand, the aversive activation function has higher gain from relatively lower-to-moderate level of negative input than the activation function for positivity (See Figure 1; Cacioppo et al., 2011). Having these activation patterns provides evolutionary benefits so the organism can readily explore the environment for resources such as food and mate in the absence of threat while staying vigilant for potential danger. In survival terms, avoiding potentially life-threatening danger is more survival-critical (e.g., quickly running away from a lion) than approaching a potential resource, such as a delicious fruit. The fruit may well remain tasty at another time, whereas there is no second chance for the organism if the lion is not successfully avoided.

Figure 1.

Differential Motivational Activation Gradients Adapted from Cacioppo et al., 2011



The framework of approach-avoidance motivation and underlying activation patterns can provide a clearer understanding of how player behaviors in virtual worlds are organized. Because humans use perceptual organs and motivational systems evolved to survive in the real world when interacting with media and virtual environments, users' bodily responses exhibit automatic appetitive or aversive activation to virtual objects and environments with varying motivational relevance (A. Lang, 2014; Reeves & Nass, 1996). For example, the startle reflex (e.g., eyeblink to sudden noise) is often used as a measure of aversive activation, given the function of the eyelid is to protect vulnerable parts of the body from potential threats (P. Lang, 1995). J. Lee and A. Lang (2016) measured the startle reflex users show while navigating in virtual rooms embedded in a video game that systematically varied levels of light and pleasantly valanced imagery. Light and pleasantness of the laboratory were also manipulated. Participants overall exhibited greater aversive activation (larger startle) effects in the dark virtual environment, which is a naturally aversive context. This result suggested that users respond to features of the virtual environment as if they were embedded in the real world.

Automatic motivational activation such as startle reflex, orienting, and attention allocation is most relevant at the very beginning of a causal chain of motivated responses elicited by an environmental stimulus (A. Lang, 2006). For example, a player may approach, move, or pay attention to resources and possibilities, and avoid or pay cautious attention to threats, enemies, and warnings in the game. Taken together, I predict that initial behavioral responses would be shaped by what players have learned in the real world in terms of beneficial and harmful possibilities. To test this, the first set of hypotheses are posed:

H1. Individuals' initial behavioral responses to the virtual environment will be shaped by motivational relevance of the environment, such that (**H1a**) resource-based objects, events, and possibilities in VE will facilitate behaviors toward active exploration and resource-mining, whereas (**H1b**) threat-based features in VE will inhibit approach behaviors and **(H1c)** facilitate avoidance reactions.

Individual Differences in Behavioral Development

The predictions based on approach and avoidance motivation guide us to investigate user behavior as adaptive responses shaped by the virtual environment. Throughout gameplay, players observe that actions they perform yield changes in the position, size, state, or shape of the virtual avatar or environment on the screen. Accordingly, players perceive action capabilities and motivational relevance from their avatar's perspective, situated in the virtual environment, instead of the perspective in the real world. The environmental changes made by players actions simultaneously generate new information to perceive, so that individual player behavior will be built on different trajectories of perception and actions (A. Lang et al, 2018).

However, it is still unclear which behaviors exhibit individual variability, and how this variability is related to development of approach and avoidance motivation over time. If individuals have differential sensitivities to opportunities (appetitive feature) and threats (aversive feature) in the virtual world, we should be able to see different patterns in behavior that reflect over-time learning of game affordances and development of higher order goals. The next paragraphs delineate this process by incorporating the concept of affordances (J. Gibson, 1979) with individual differences in trait motivational reactivity (Carver & White, 1994; Carver, 2006; A. Lang, Kurita, Rubenking, & Potter, 2011).

J. Gibson's ecological perception theory (1979) proposes the term *affordances* to refer to combined properties of an object or situation in the environment to be perceived as action capabilities (i.e., 'what I can do with them'). Perceiving affordances is a relational process between an individual's capacity and the environmental properties. For example, one automatically perceives a chair as 'sit-able' from its surface flatness, solidity, and height relative to their own body size. Affordances are also task-specific, meaning that people perceive different action capabilities for different goals. A "sittable" chair will be perceived as a surface to step on when one attempts to reach the power cord from ceiling fans. J. Gibson (1979) states that affordances are fundamentally about detecting what is beneficial (appetitive) or injurious (aversive) in the environment for one's survival. Movement and time are essential parts in ecological perception, as an organism automatically detects motivationally relevant information from its own movements. Perceiving affordances mediated by action is closely tied to learning, which in ecological terms, means becoming attuned to perceiving and precisely using specific sets of affordances for a given task (E. Gibson & Pick, 2000). That said, the concept of affordances is central to understanding learning in video games and virtual environments (Gee, 2008; Linderoth, 2012).

Because users can interact with various contents of a video game at different times and frequencies, the trajectory of learning and using game affordances should show a highly individualized variability over time, changing over several developmental stages (A. Lang et al., 2018). When experiencing a novel virtual environment, players are likely to exhibit responses they would normally show in the real world (J. Lee, Eden, Ewoldsen, Beyea, & S. Lee, 2019). Thus, individual variability at initial stages may be low, as behavior should be primarily shaped by initial motivated responses (approach and avoidance) to immediate resources and threats. However, as individuals explore the environment, the affordances they learn during the exploration will guide them to develop their own behavioral trajectories until they achieve a certain level of mastery and preference of behavioral choices. When players have learned all (or most) affordances of the virtual environment, player behavior should be reduced to a sizable number of patterns that are optimal for pursuing individual goals or challenges.

To date, only a few studies have analyzed user-generated individualized content from gameplay. For example, Weber and colleagues (2009) content-analyzed players' first-person shooter (FPS) gameplay sessions in terms of frequency and duration of action sequences and events, and identified 483 unique action sequences. However, only a portion of those sequences (i.e., 16) accounted for the majority of play time, suggesting stability of certain behavioral patterns overtime or across different individuals. Furthermore, A. Lang and colleagues (2018) demonstrated qualitatively different learning trajectories during videogame play by analyzing overtime frequencies of performed behaviors among players of Grand Theft Auto. Specifically, some players firmly stabilized driving behaviors as they would in the real world (i.e., driving for safety, not hitting pedestrians, and not dying), while other players instead showed an increase in violent driving and purposeful dying in the game, which was orthogonal to behaviors enacted in the real world (safe driving). This result implies the importance of identifying individual differences that bring about different patterns of in-game behaviors over time, rather than considering a game environment to have a uniform effect across all individuals and all game play instances.

With an intention to focus on the individual factors fundamentally relevant to users' approach and avoidance motivation, this study investigates the moderating role of individuals' *trait motivational reactivity* in facilitation and inhibition of motivated behavior over time. Trait motivational reactivity refers to individual differences in the reactivity of their appetitive (approach) and aversive (defensive) motivational systems to the environment (Carver & White, 1994; Carver, 2006; A. Lang, Kurita, Rubenking, & Potter, 2011). In the game context for example, a player with high appetitive system reactivity (ASA) may go toward a loot box despite the risk of getting attacked by a monster, whereas those with high defensive system reactivity (DSA) may refrain from approaching the box. Over time, the accumulated approach and avoidance actions players perform with this differential sensitivity can cause qualitatively distinct play patterns to emerge.

Various measures have been developed to indicate differential reactivity of motivational systems, such as the measure of behavioral inhibition and excitation system (BIS/BAS; Carver & White, 1996). The trait motivational reactivity measure used in this study is Motivation Activation Measure (MAM; A. Lang et al., 2007; 2011), given that it incorporates relative gradients in the level of appetitive and aversive activation as trait-based reactivity. MAM independently measures the level of appetitive system activation/reactivity (ASA) and defensive/aversive system activation/reactivity (DSA), which refer to individual differences in reactivities of the positivity offset (ASA) and negativity bias (DSA) defined in the evaluative space model (ESM; Cacioppo et al., 2011). Specifically, some individuals have higher sensitivity in the appetitive system in reaction to positive offerings in the environment, thus are more engaged in the pursuit of approach-related behaviors, especially in neutral or positive context. Conversely, some individuals are more reactive to potential threats in the environment, thus are more likely to show rapid inhibition of approach-related behaviors or facilitation of defensive behaviors with presence of even low level of threats. Four trait motivational reactivity groups can be identified based on ASA and DSA ranging from high to low: risk takers (high ASA and low DSA), risk avoiders (low ASA and high DSA), coactives (high ASA and DSA), and inactives (low ASA and DSA).

Altogether, this study argues that individual differences in motivational trait reactivity will shape baseline effects on how their appetitive and aversive motivational systems will react to motivationally relevant (appetitive or aversive) information in the game environment in terms of opportunities and threats. Trait motivational reactivity is also predicted to influence the rate in which individuals' approach and avoidance behaviors are facilitated or inhibited. In short, the second set of hypotheses are formulated:

(H2a) High ASA will be associated with more facilitated performance of approach-related behaviors under lower level of threat, while **(H2b)** High DSA will be associated with inhibited approach and facilitated avoidance-related behaviors with presence of threat. **(H2c)** For individuals with high DSA, facilitation in avoidance-related behaviors will be faster and stronger than the rate of facilitation in approach-related behaviors.

Observing Development of In-game Motivated Behavior

Yet, which behaviors will be grouped by which users during gameplay? To observe in-game behaviors in terms of approach and avoidance motivations, it is important to identify affordances and motivationally relevant contents in a specific game environment. Different game environments may offer only a portion of possible behaviors in the real world, making some affordances more salient or limited than others. For example, games such as *Grand Theft Auto* are designed to provide affordances for criminal and violent actions (e.g., weapons, robbery), while some other games such as farming simulation focus on objects and tools for gardening and farming and may not contain features associated with violent behavior.

Hunicke, LeBlanc, and Zubek (2004) conceptualized game affordances as a combination of player actions and control mechanisms that make the actions actually happen in the game. These game affordances specify various levels of in-game interactions such as controlling virtual character(s) and objects (e.g., a button press to enter a virtual portal to teleport) and competition or reward systems. The composition of these affordances varies in different games and virtual environments. Because game affordances are designed and programmed by developers, available information linked with the affordances (e.g., visual, interface) may not be directly picked up for user perception (Gaver, 1991). In this sense, players who just entered a new virtual environment would need to verify or discover the links between game features and control mechanisms and learn game affordances by interacting with information in the game environment.

In this regard, the current study first defines the structure of game environment and affordances situated in the particular virtual environment participants will explore and learn. Specifically, the environment simulating a commercial game *Minecraft* (Mojang, 2011) was selected to examine user behavior. As a sandbox game, Minecraft players show a wide range of individual variability in possible player behavior (Duncan, 2011). In the standard gameplay mode, the game is designed to motivate players to engage in various survival relevant behaviors. The ways to achieve the survival goal include mining resources, crafting, and building to overcome challenges of life-threatening monsters spawned during night times. Duncan (2011) describes the experience from Minecraft play as *emergent gameplay* that evolves from exploring game affordances to expressing creativity. That is, the game uses a survival challenge to encourage players "to explore the space, learn to build, and then actually construct within the first few minutes of the game" (Duncan, 2011, p. 11). The game provides a vast environment consisting of 3D blocks representing various materials. Players can mine those resources and use them to craft items or construct building structures in a similar way to play with LEGO blocks. The game does not provide a linear narrative to follow, therefore players need to figure out their ways to play by exploring the opportunities and threats in the game. Then players' engagement throughout exploration brings about intrinsic motivation for creative works that are considered as complex and advanced play. That said, some players may choose to design and construct more aesthetically pleasing, creative, or complex structures, whereas some other people may take a challenge to survive effectively in extremely hostile settings.

While the game affordances in Minecraft primarily focus on actions for resource-mining, crafting, and building, the variable player trajectories from basic actions to advanced behaviors should indicate development of motivated behavior and learning affordances for higher-order goals across players with different motivational traits. Evidently, players are allowed to perform any available actions in the game, but some advanced actions in the game such as crafting require player knowledge or precedent lower level actions like knowing recipes and collecting ingredients. By exploring and practicing lower level actions, players' perception and action will become more fine-tuned to aspects of the game environment relevant to advanced behavior and individual goals (Linderoth, 2012). Therefore, by observing when and how often an individual engages in approach versus avoidance-related behaviors, we can explain how development of individual behavioral patterns happens (A. Lang et al., 2018). We can also interpret learning of in-game affordances based on whether game features invite approach or avoidance behaviors in players, and how these behaviors change over time as game affordances are learned.

Using player-generated behavior to examine psychological constructs, such as motivations and personality, is not a novel concept. For example, Canossa, Martinez, and Togelius (2013) investigated behavioral logs from Minecraft players in terms of life motivation categories in Reiss Motivation Profile (RMP; Reiss, 2008), and found some motivation constructs are more correlated with in-game environments, including curiosity with the number of items used/crafted and idealism with using less injurious items. The researchers analyzed a wide variety of parameters that could be extracted from game data logs, including total play time, the number of worlds played, distance travelled via different ways of locomotion, different items that were mined and crafted, and many others.

However, Canossa et al. (2013) collected these data online as aggregated logs, thus participants' total play time, maps, and game modes seemed to vary greatly across different participants. Experimental manipulation is not feasible in this setting, making it hard to estimate in what contexts participants performed different actions. Furthermore, researchers cannot address how different players develop certain behavioral patterns with normalized data. Additionally, the life motivation constructs used in the study could have been confused in terms of underlying motivational orientations (approach and avoidance) and intensity. Those constructs also did not specify behaviors from lower to higher levels or those that develop throughout shorter or longer timescales. For example, discrete motivations of "eating" and "honor" in RMP (Reiss, 2008) can be all considered approach-based motivations, but the former is likely to be initiated by primary biological motivators (e.g., food) that automatically elicit appetitive motivational activation (P. Lang, Greenwald, Bradley, & Hamm, 1993), whereas the latter may be learned in one's social context through relatively longer developmental timescale.

In contrast, the current study organizes available actions (i.e., affordances) in the game environment based on motivational orientations as well as motivationally relevant contexts in which distinctive behaviors emerge. Approach and avoidance orientations are investigated at multiple levels of behaviors, ranging from relatively lower and automatic behaviors to higher levels, such as deliberate and controlled behaviors. Although this study uses behavioral parameters similar to those identified in Canossa et al. (2013), the analytical framework of this study involves both time and context aspects of behaviors. In other words, I extract both moment-by-moment activities and accumulated experiences from the data, examining both automatic/early responses to motivationally relevant information and formation of relatively stable behavior patterns. Understanding underlying motivation for a given behavior would be also better achieved when incorporating the context in which certain behaviors occur. For example, the frequency of actions performed in a threatening context (e.g., presence of monsters) can indicate facilitated avoidance behavior (e.g., increased running away) or inhibited approach behavior (e.g., decreased collecting) compared to a safe context. Table 1 illustrates categorization of in-game approach and avoidance behaviors which will be used to examine behavioral trajectory development over time.

Table 1.

Behavioral Indicators of Approach and Avoidance Motivations

Motivational Relevance	Motivated Response
Appetitive/opportunities	Facilitated exploration
	Moving toward and object
	Collecting resources
	Crafting items
	Building
Aversive/threats	Inhibited exploration
	Moving away from an object
	Hiding
	Engaging in combats

Yet, categorizing indicators of approach and avoidance should be done with caution given the ambiguity in combination of different motivational inputs, especially in higher order behaviors. Although the ESM effectively explains motivational reactions for survival at the basic level, when it comes to more complex behavioral processes and outcomes, the picture gets less clear. Indeed, there are instances when initial motivational inputs may not directly result in behavior or subjective feelings that are congruent with the direction of motivational activation

(Elliot & Covington, 2001). To illustrate, the presence of a delicious-looking dessert may initiate automatic activation in the appetitive system, but the predisposition to approach it may be suppressed by the individual's higher order goal to lose weight. Furthermore, different motivational inputs involved in a sequence of behaviors may eventually lead to a behavioral outcome that can be observed as either approach or avoidance. For example, frustration (i.e., aversive activation from the negative event) may result in facilitated approach behaviors toward achievement of the goal (Carver & Harmon-Jones, 2009). Therefore, while activities of building and crafting can be considered as approach-related behaviors at first glance, those behaviors may be primarily guided by avoidance or defensive motivation to protect themselves from nighttime monsters. Moreover, defensive actions can also be clarified in terms of fight or flight responses, such as the goal of attacking or running away from the enemy.

Intuitively, complex behaviors are developed upon learning and attunement of fundamental and low-level behaviors (E. Gibson & Pick, 2000). In a game like Minecraft, low level behaviors are basic locomotive actions and simple clicking to move the avatar or collect an object. While testing specific hypotheses for basic approach and avoidance via locomotion and collecting, this study takes a more exploratory approach to analyzing relatively advanced in-game behaviors. Examples of more complicated actions include using advanced tools, crafting, defeating enemies, and building.

Taken together, this study investigates in-game behaviors and pre-game assessment of motivational reactivity to explore trajectories of behaviors over time in a virtual environment. In addition to conceptual hypotheses articulated earlier, the following exploratory question is asked: RQ1. To what extent does trait motivational reactivity moderate approach and avoidance behaviors in different levels?

METHOD

Participants

A total of 127 participants were recruited via college participant systems. Participants received either extra credit (if recruited from the student participants pool) or monetary compensation ($20; if recruited from the paid participants pool). Data from two participants were excluded due to technical glitches with rendering the game map. Thus, data from 125 participants (54.4% male, 45.6% female) were used for behavioral data analysis. Participants' age ranged from 18 to 41, with an average of 21.6 years. By random assignment, 64 were assigned to the survival condition and 61 were assigned to the free exploration condition. The study protocol, instruments, and procedure were approved by the institutional review board.

Procedure

Upon arrival to the lab, participants completed an informed consent form, and responded to pre-survey questionnaires measuring trait motivational reactivity (miniMAM; A. Lang et al., 2011), previous gaming experience, self-reported videogame play time in daily life, and gaming levels. Participants then practiced a short tutorial session with the researcher's assistance to learn controls and main interfaces of the game (See Appendix C). During the tutorial, participants were instructed that there was no explicit challenge or task other than exploring the game. Participants were also informed about the monsters to be spawned during the night (for both conditions), the safe zone (for both conditions), and the hunger system (in the survival mode only). Then participants played the game stimulus for 40 minutes while their game behavior was being tracked and video recorded. In-game messages appeared to indicate the beginning of the first day, first night, second day, second night, and the end of gameplay. After gameplay, participants responded to post-game survey questionnaires asking about perceived positivity, arousal, and negativity of the game environment in different contexts (day and night). After the post-game survey, a trained researcher asked structured post-game interview questions about participants' feelings, subjective experiences, and intentions underlying behaviors they performed[1]. At the end, participants were thanked for their time and compensated.

Stimuli

An open world computer game stimulus was created simulating an existing video game, Minecraft (Mojang, 2011), using Unity 3D engine. Similar to Minecraft, the game environment consisted of 3D cubic blocks of terrain resources represented in different textures and colors. Participants played the game in the first-person perspective. Procedural generation algorithms were used to create the entire map, and structure, landscape, and placement of resources were constant across different conditions and participants (for background information, see Freiknecht & Effelsberg, 2017).

To control game features outside the study scope, types of resources and threats implemented in this study were simplified compared to the commercial game. Specifically, three resource types were available or craftable in the game environment: **food** (raw berries and cooked meals), **building materials** (wood, stone, ore, etc.), and **tools** (weapons, paints, and mining/building tools). Recipes for craftable items with required resource ingredients were available in the 'recipe' interface. Primarily supported behaviors were moving around, collecting resources via harvesting berries or mining blocks, attacking monsters, and building and crafting items using the collected resources.

The game environment featured a day and night cycle with a 20 minutes long interval between each day. There was no other creature in the game during the daytime. In the nighttime,

[1] The post-game interview responses were collected for future analysis not for hypothesis testing in this study, hence interview data are not presented in the manuscript.

monsters randomly appeared within the 35-50 meters range from the player character's location. When a player was within ten tiles (about ten meters in the game) from a monster, the monster chased the player to attack. The game also featured a safe zone around the player's starting position that keeps monsters from coming into the area. A detailed description of game elements can be found in Appendix A and Figure 2.

Figure 2.

Screenshots of the Game Stimulus

Note. This figure shows (a) The starting position in the game at the safe zone, (b) resource gathering in the game field using a shovel tool, (c) the inventory and crafting interface, and (d) the encounter with the monster during the night.

Experimental Design

The study design employed a 2 (game mode: survival challenge and free exploration) × 2 (time of day: day and night) × 2 (repetition) mixed factorial design. The game mode was the between-subject independent variable, and the varying levels of threat through the day and night cycle as well as repetitions were within-subject independent variables.

Gameplay Mode

Participants were randomly assigned to either a *survival* or *free exploration* play mode. In the survival mode, participants had functional hunger (energy) and health systems making the opportunities (i.e., resources) and threats (i.e., hunger and enemies) critical to the character's survival. The game started with 100 energy (satiety) and health points. The energy level decreased by 10 points every 40 seconds. The health level decreased by 15 points when attacked by a monster. The player character could die when either the energy or health level became a zero and reappear at the starting position with 20 percent of energy and health restored. In order to maintain health, participants had to regularly fetch and consume food resources to replenish energy and health or avoid attacks from monsters to survive. In the free exploration condition, participants did not incur energy loss or health damage from failing to consume resources or defend themselves. Monsters still chased and attacked the player during the night but did not cause any damage to the player character.

Nighttime Threat

During the daytime, the game exhibited ambient daylight with an overall pleasant environment and no monsters, whereas the nighttime contained roaming monsters and ambient darkness. A monster spawned every five seconds but the number of monsters around the player did not exceed 10 in a set range from the player (perceived at about 50m). Although the consequences of nighttime threat would be higher in the survival condition, darkness, and presence of monsters in the free exploration condition was also expected to induce moderate threat compared to the daytime. A day-night cycle was 20 minutes long (10 minutes of daytime and 10 minutes of nighttime).

Measures and Dependent Variables

Trait Motivational Reactivity

Motivational Activation Measure (miniMAM; A. Lang, Kurita, Rubenking & Potter, 2011) was used to measure individual differences in reactivities of appetitive and aversive motivational systems. Upon arrival at the lab, participants viewed each of the 41 MAM images that contain 14 positive images and 21 negative images with varying levels of arousal. After viewing each MAM image, participants rated perceived positivity, negativity, and arousal level of the image based on a 9-points scale asked in a randomized order. These ratings were then used to calculate each participant's ASA (approach system reactivity, positivity offset) and DSA (defensive system reactivity, negativity bias). Formula for individual ASA and DSA scores are specified as follows (A. Lang et al., 2007; A. Lang et al., 2011):

ASA = (Mean positivity rating of positive images with arousal level 6) – (Mean positivity rating of both positive and negative images with arousal level 1)

DSA = (Mean negativity rating of negative images with arousal level 3 and 4) – (Mean negativity rating of both positive and negative images with arousal level 1).

After calculating each participant's ASA and DSA scores, a median split was performed to categorize the scores to high or low ASA and DSA groups in line with A. Lang et al. (2007; 2011).

Motivated Behavior

All in-game behaviors participants performed during gameplay were automatically tracked with timestamps. For each event, the timestamp, spatial coordinates of the target, character's status at the moment (i.e., health and hunger level, character location), and type of the event were recorded. Aggregated data were created to log instances of player actions in different categories as frequencies or time spent on an action across four in-game time conditions (first day, first night, second day, second night), resulting in 29 fine-grained action parameters. Among these action parameters, six behavioral parameters central to my hypotheses were extracted based on approach and avoidance indicators introduced in Table 2: exploration (travel distance), collecting (the number of items collected), crafting (the number of items crafted), building (the number of blocks stacked), hiding (time spent in the safe zone), and engaging in combat (the number of monsters killed). Appendix B provides detailed information on all parameters and the structure of data.

Table 2.

Operationalization of In-game indicators for Motivated Responses

Motivational Relevance	Motivated Response	In-game Indicators
Appetitive/opportunities	Facilitated exploration	Increased travel distance
	Moving toward an object Collecting resources	Increased number of collected objects
	Crafting items	Increased number of items crafted
	Building	Increased frequency of building
Aversive/threats	Inhibited exploration	Decreased travel distance
	Moving away from an object	Decreased number of collected objects
	Hiding	Increased time spent in the safe zone
	Engaging in combats	Increased frequency of killing

Note. In this operationalization, "collecting" was considered as a combination of moving toward an object and actual collecting action because the game mechanics required participants to move close to an object to pick it up.

Facilitation of approach behavior was indexed by the increase in **travel distance, collecting, crafting, and building activities.** Inhibition of approach behaviors were indexed by the decreased number in instances of approach behaviors during the night, such as decrease in crafting or building activities. Facilitation of avoidance or defensive behaviors was indexed by increased time spent **hiding** (in a safe zone) as well as instances of **killing**.

Covariates

Player skills and previous gaming experience are associated with their behavior in games (Schrader & McCreery, 2008; Matthews & Weaver, 2013). Thus, participants' experiences with video games may naturally covariate with their learning and use of game affordances, as well as motivation for advanced behaviors. To control for these effects, the pre-survey asked two questions on video game experience. The first asked about participants' gameplay time in a typical week on a four-point scale (i.e., "how many days do you spend at least 30 minutes playing a video game?") and the second about their self-reported level of engagement with video games (i.e., whether participants considered themselves to be a casual, mid-core, or hardcore gamer).

RESULTS

Manipulation Check

The motivational relevance manipulation was successful according to the self-report post-game survey responses. Average ratings for positivity of the environment showed that the daytime environment was perceived more positively (M = 6.7, SD = 1.69) than the nighttime (M = 4.14, SD = 2.29), $t(123)$ = 11.34, p < .001. The nighttime environment was rated more negatively (M = 5.6, SD = 2.45) than the daytime (M = 2.86, SD = 1.94), $t(124)$ = 10.7, p < .001. The nighttime was also perceived to be more arousing (M = 5.99, SD = 2.41) than the daytime (M = 5.25, SD = 2.07), $t(124)$ = 2.97, p < .01.

Normality Check

Table 3 summarizes the extent to which participants (N = 125) engaged in game behaviors categorized as approach- or defensive-orientations in this study. Due to the wide individual variability shown in the raw data, distributions of each parameter were screened for normality. First, skewness and kurtosis were assessed considering an absolute skewness < 2 and kurtosis < 7 as acceptable range (Kim, 2013). Four parameters (crafting, building, hiding, and killing) had a skewness higher than 2.0, and two parameters (building and killing) had a kurtosis exceeding 7.0. Visual inspection of histograms also confirmed that distributions of those parameters deviated from normality. Therefore, a square root transformations of crafting, building, hiding, and killing data were performed on each data cell as a log transformation is not suitable for count data containing zeros and ones (O'Hara & Kotze, 2010; Osborne, 2002). After the square root transformation, both skewness (.23 to 1.47) and kurtosis (-1.25 to 1.6) were in the acceptable range.

Table 3.

Descriptive Statics of Motivated Behaviors

Motivated Behavior	Daytime				Nighttime			
	Min	Max	M	SD	Min	Max	M	SD
Approach Behavior								
Traveled Distance	414.14	4396.66	2110.22	892.73	176.45	6108.96	2611.71	1301.39
Collecting	41	642	238.08	111.61	16	397	173.37	81.81
Crafting	0	57	11.86	12.07	0	56	10.68	12.15
Building	0	271	45.67	53.76	0	349	46.13	63.49
Defensive Behavior								
Hiding Time	2.5	671.42	105.54	149.88	0	1082.13	382.78	279.48
Killing	-	-	-	-	0	147	20.9	24.31

Note. The statistics are based on the raw data before transformation of four parameters (building, crafting, hiding killing).

Analyses

A set of repeated measures analysis of variance (ANOVA) was conducted using the aggregated data to test hypotheses on two key formative drivers of game behavior: (1) motivationally relevant features in the game environment (H1a, H1b, and H1c), and (2) individuals' motivational traits (H2a, H2b, and H2c). In each statistical model, one of the six distinctive motivated behaviors (**travel distance, collecting, crafting, building, hiding, killing**) was included as a dependent variable, time of day and repetition as within-subject independent variables, and play mode condition and participants' ASA and DSA groups (high or low) as between-subject variables. To control for previous gaming experience, participants' self-reported videogame play time in daily life (playtime) and level of engagement (level) were included as covariates.

Effects of Motivational Relevance

The first set of hypotheses (H1a-H1c) investigated whether motivational relevance of the virtual environment shapes users' adaptive responses, including facilitation of exploration and approach-related actions in the appetitive environment (H1a), inhibition of approach-related actions (H1b) as well as facilitate defensive actions (H1c) in the threatening (aversive) environment.

Approach-oriented Behavior

Table 4 summarizes results from a set of repeated measures ANOVAs to test H1a and H1b regarding the effect of motivationally relevant features in the game environment on approach-oriented behavior (**travel distance, collecting, crafting, building**). All results can be found in Table 4 including both significant and non-significant results, and significant findings are discussed in detail below.

Table 4.

Test Statistics for Approach-oriented Behavior (H1a and H1b)

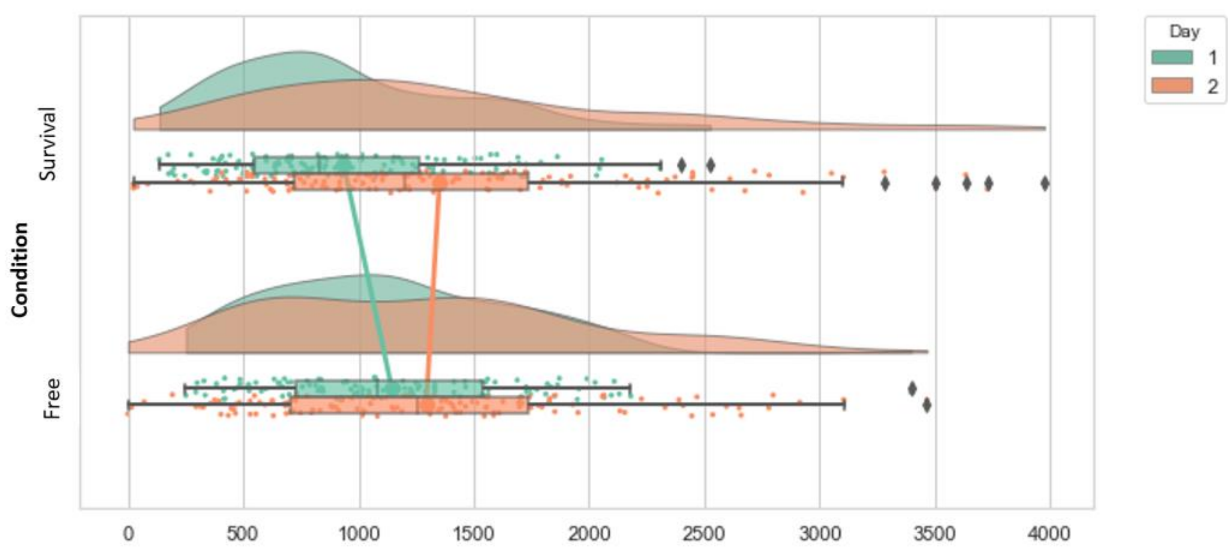
Effect	F	p	$\eta_p{}^2$	F	p	$\eta_p{}^2$	F	p	$\eta_p{}^2$	F	p	$\eta_p{}^2$
	Travel Distance			Collecting			Crafting			Building		
Time	.12	.73	0	7.499	.007 **	.06	1.181	.28	.01	.958	.330	.01
Time × Playtime	.511	.476	0	.198	.658	0	.428	.515	0	.42	.518	0
Time × Level	3.207	.076	.03	.002	.963	0	.805	.371	.01	0	.997	0
Time × Condition	.322	.572	0	12.473	.001 **	.1	8.099	.005 **	.07	.349	.445	0
Repetition	7.524	.007 **	.06	2.078	.317	.01	1.487	.225	.01	.098	.754	0
Repetition × Playtime	.099	.754	0	1.012	.317	.01	1.213	.273	.01	5.576	.02 *	.05
Repetition × Level	.341	.561	0	1.072	.303	.01	.585	.446	.01	.439	.509	0
Repetition × Condition	5.895	.017 *	.05	12.281	.001 **	.1	1.35	.248	.01	2.731	.101	.02
Time × Repetition	.002	.965	0	3.614	.06	.03	2.072	.153	.02	2.577	.111	.02
Time × Repetition × Playtime	1.216	.272	.01	2.9	.091	.031	1.51	.222	.01	.017	.898	0
Time × Repetition × Level	.949	.332	.01	.817	.368	.01	1.848	.177	.02	1.552	.215	.01
Time × Repetition × Condition	.484	.488	0	.245	.621	0	4.805	.03 *	.04	.126	.723	0

Note. The degree of freedom (*df*) for all statistics listed in the table is (1, 115). Significant results are marked with * ($p < .05$), ** ($p < .01$), and *** ($p < .001$).

Travel Distance. Participants traveled further distance during the second half of gameplay (day 2, *M* = 1313.67, *SE* = 33.5) than the first half (day 1, *M* = 1025.29, *SE* = 58.26), *F*(1, 115) = 7.524, $p < .01$, η_p^2= .06. The interaction effect between conditions and repetitions further indicated that the increase in travel distance in the second half was bigger in the survival condition ($MD_{second\text{-}first}$ = 416.32) than the free exploration condition ($MD_{second\text{-}first}$ = 160.45), *F*(1, 115) = 5.895, $p < .05$, η_p^2 = .05. Furthermore, as shown in Figure 4, variability in travel distance was much bigger for the second day than the first day in the game. However, the nighttime threat did not significantly vary travel distance, *F*(1, 115) =.12, $p > .05$, showing no significant inhibition of spatial exploration induced by threat.

Figure 3.

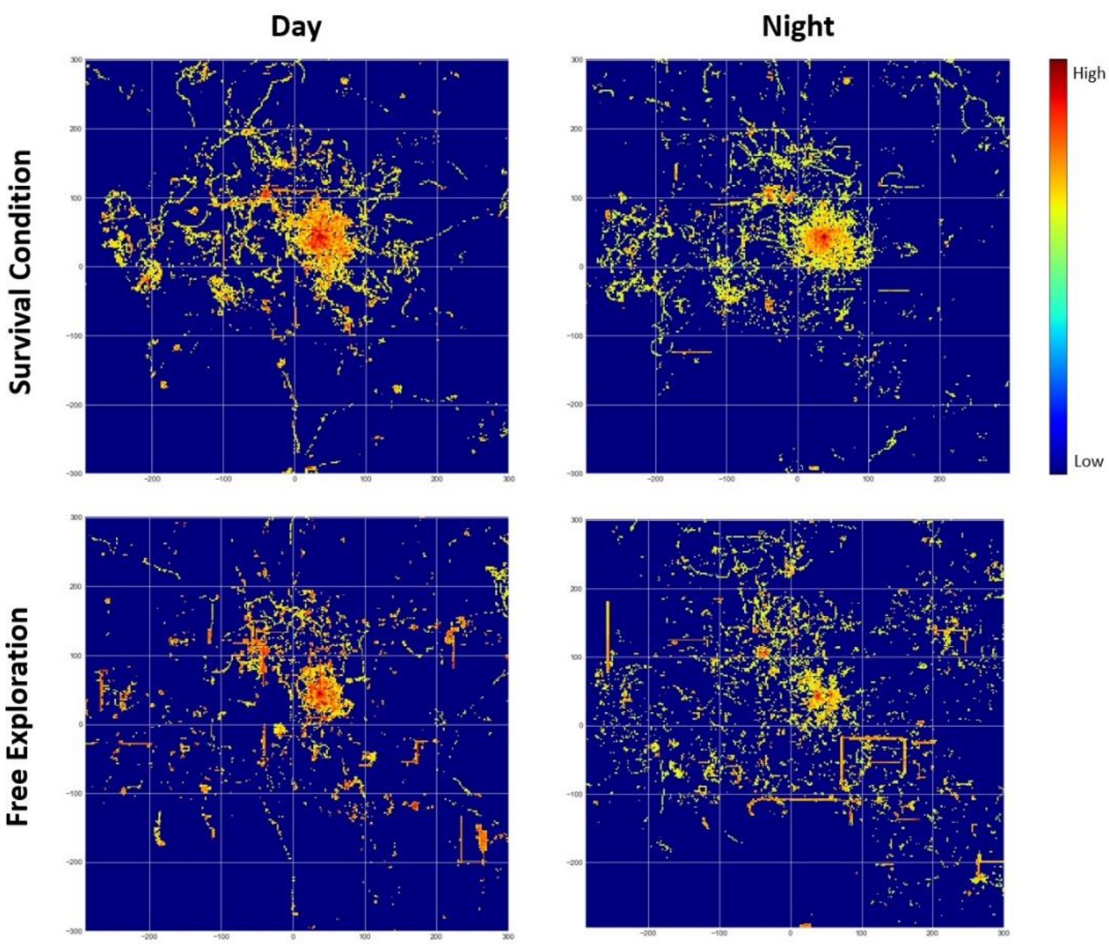
Variability in Travel Distance across Conditions and Repetitions



To further explore spatial traces of player behavior, heatmaps of accumulated actions on the spatial map for four combinations of conditions and day/night contexts were created (Figure 4). Figure 4 shows that although the "spread" of player activities did not visually differ between the daytime and nighttime, accumulated activity level was higher during daytime (indicated in red) than nighttime within traveled areas. This implies that approach behavior is not limited to expanding exploratory locomotion and can involve performing other types of actions in a focused area (e.g., collecting, building). Also, participants' spatial trajectory was relatively centered around the middle of the map (the starting point) in the survival condition compared to the free exploration condition. This indicates participants may have moved back and forth within already explored area in situations when intaking resources and preparing for potential threat were important for survival. Conversely, spatial trajectory during free exploration tended to focus on visiting unexplored area rather than staying in one position.

Figure 4.

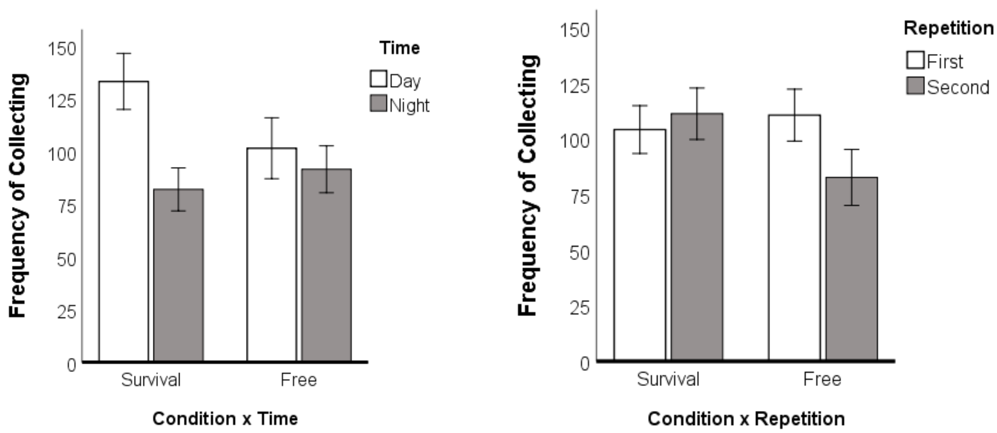
Heatmaps of Player Positions with Accumulated Actions in All Categories



Collecting. Consistent with H1a and H1b, the main effect of in-game time revealed that collecting was facilitated during the daytime (*M* = 117.36, *SE* = 4.94), and inhibited during the nighttime (*M* = 86.8, *SE* = 3.76), $F(1, 115) = 7.499$, $p < .01$, $\eta_p{}^2 = .06$. The interaction effect between conditions and time also showed that facilitation of collecting during the daytime was more salient in the survival condition than the absence of threat in the free exploration condition, $F(1, 115) = 12.473$, $p < .01$, $\eta_p{}^2 = .1$ (See Figure 5a). Over time, instances of collecting significantly decreased on the second game day in the free exploration condition and slightly increased in the survival condition, $F(1, 115) = 12.281$, $p < .01$, $\eta_p{}^2 = .1$ (See Figure 5b).

Figure 5.

Collecting Frequency across Conditions: (a) Day/Night (b) Repetitions

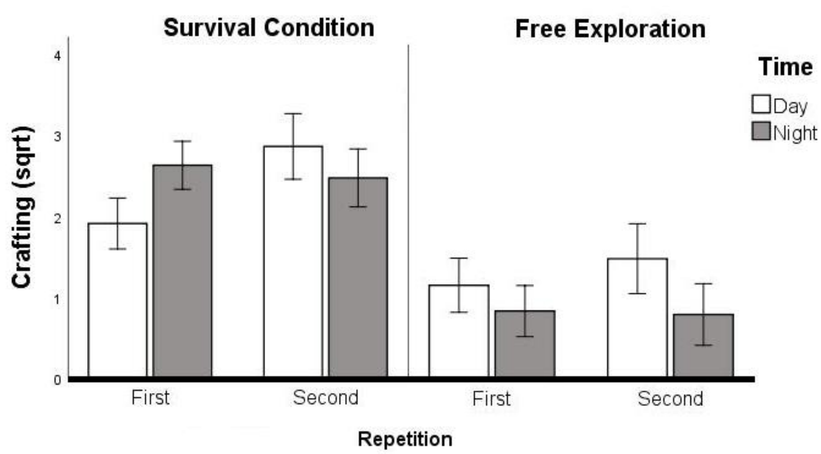


Note. Error bars represent the 95% confidence intervals around the values.

Crafting. Each instance of crafting was logged when a participant created an item using the workbench based on in-game recipes. The repeated measures ANOVA test was conducted using the square-root of the crafting frequency due to normality violations. Crafting was facilitated in the survival condition, especially during the nighttime (*M* = 2.55, *SE* = .15) followed by daytime (*M* = 2.39, *SE* = .14). This trend was the opposite for the free exploration condition, which had relatively higher crafting frequency during daytime (*M* = 1.35, *SE* =.17) than the nighttime (*M* = .84, *SE* = .15), *F*(1, 115) = 8.099, p < .05, $\eta_p{}^2$ = .07. Furthermore, the three-way interaction between conditions, time of day, and repetitions found that in the survival condition, crafting increased overtime during the first half and decreased in the second half in the survival condition. In the free exploration condition, which showed inhibited crafting overall, crafting activity slightly increased during the daytime and decreased in the nighttime, and this trend was stable across repetitions, *F*(1, 115) = 4.805, p < .05, $\eta_p{}^2$ = .04. In both conditions, most crafting occurred during the daytime of the second repetition (See Figure 6).

Figure 6.

Frequency of Crafting Behavior: Condition × Time × Repetition Interaction



Note. Error bars represent the 95% confidence intervals around the values.

Building. Building behavior was quantified by logging the number of blocks placed by participants and taking the square root of the frequency data. Although participants placed more blocks during the second day (*M* = 4.02, *SE* = .25) than the first day in the game (*M* = 3.28, *SE* = .18), the significant covariance between the effect of repetition and playtime (i.e., time spent playing videogames on regular basis) also indicates that participants who play videogames more often placed more blocks to build during the later phase of gameplay, $F(1, 115) = 5.576$, p < .05, $\eta_p{}^2 = .05$. There was no systematic facilitation or inhibition of building activities caused solely by variations in motivational relevance of the environment.

Defensive Behavior

Table 5 presents all results from a set of repeated measures ANOVAs to test H1c regarding facilitation of defensive behavior (hiding, killing) shaped by environmental threats.

Table 5.

Test Statistics for Defensive Behavior (H1c)

Effect	*F*	*p*	$\eta_p{}^2$	*F*	*p*	$\eta_p{}^2$
		Hiding			Killing	
Time	14.143	.000 ***	.11		-	
Time × Playtime	.852	.358	.01		-	
Time × Level	.745	.39	.01		-	
Time × Condition	36.311	.000 ***	.24		-	
Repetition	5.977	.016 *	.05	1.954	.165	.02
Repetition × Playtime	.929	.337	.01	.825	.366	.01
Repetition × Level	.26	.611	0	.129	.72	0
Repetition × Condition	4.146	.044 *	.04	3.611	.06	.03
Time × Repetition	1.715	.193	.02		-	
Time × Repetition × Playtime	.603	.439	.01		-	
Time × Repetition × Level	.303	.583	0		-	
Time × Repetition × Condition	.128	.722	0		-	

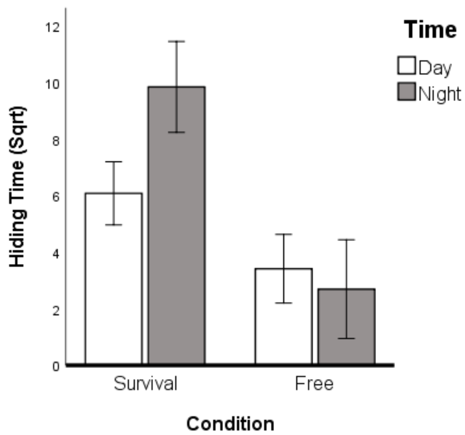
Note. Because monsters appeared only during the nighttime, the only within-subject factor for killing behavior was repetitions (first and second night). The degrees of freedom for all statistics listed in the table is (1, 115). Significant results are marked with * ($p < .05$), ** ($p < .01$), and *** ($p < .001$).

Hiding. Time spent in the safe zone (the platform at the starting position in the game) was logged in seconds to quantify hiding behavior. The square root of the time data was used for the repeated measures ANOVA test. As predicted in H1c, the main effect of time (nighttime threat) demonstrated facilitation of hiding in the aversive context, indicated by longer time in the safe zone during the nighttime ($M = 6.26$, $SE = .60$) than the daytime ($M = 4.74$, $SE = .42$), F(1,

115) = 14.1433, p < .001, $\eta_p{}^2$ = .11. The main effect of repetitions also found that hiding time decreased overtime (M_{first} = 6.81, SE_{first} = .53; M_{second} = 4.2, SE_{second} = .51). Furthermore, the interaction between the conditions and nighttime threat revealed the longest time spent hiding during the nighttime of the survival condition (M = 9.84, SE = .81) in which the induced threat level was expected to be the highest, F(1, 115) = 36.31, p < .001, $\eta_p{}^2$ = .24 (See Figure 7).

Figure 7.

Time Spent in the Safe Zone: Interaction between Condition and Time



Note. Error bars represent the 95% confidence intervals around the values.

Killing. The number of monsters killed by participants was logged to index killing behavior. The repeated measures ANOVA using the square root of killing instances did not find a significant result from repetitions. Because monsters were spawned only during the nighttime thus had only one within-subject factor (repetition), additional one-way ANOVA was performed to test the between-subject main effect of conditions. The result revealed that killing instances was significantly higher in the free exploration mode (M = 4.74, SD = 2.71) than the survival mode (M = 2.84, SD = 2.12), F(1, 115) = 19.282, p < .001, $\eta_p{}^2$ = .13

Effects Moderated by Motivational Trait

This section tests the extent to which individual differences in trait motivational reactivity (ASA and DSA) modulate players' motivated behavior in response to the game environment. I predicted that individuals with high ASA would be more prone to engaging in approach-oriented behavior (H2a), and those with high DSA would show more inhibited approach and facilitated defensive behavior (H2b). Moreover, DSA was expected to exhibit more sensitive responses to presence of threat in the environment than ASA sensitivity to absence of threat (H2c). While presenting results to test the hypotheses, this section also explores which behaviors are moderated by ASA or DSA (RQ).

How Does Trait Motivational Reactivity Modulate Approach-oriented Behavior?

Table 6 lists all results involving the effects of ASA and DSA on participants' approach-oriented behaviors (travel distance, collecting, crafting, and building).

Table 6.

Test Statistics for Modulation of Trait-motivational Reactivity: Approach-oriented Behavior

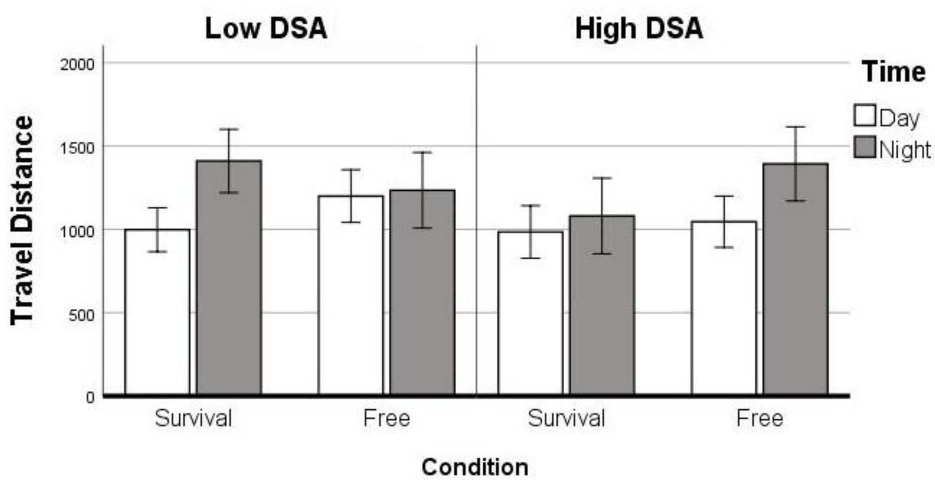
Effect	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2	F	p	η_p^2
	Travel Distance			Collecting			Crafting			Building		
Time × ASA	.002	.962	0	1.099	.297	.01	3.536	.063	.03	.024	.877	0
Time × DSA	.001	.973	0	3.115	.08	.03	.006	.941	0	.033	.856	0
Time × Condition × ASA	.112	.727	0	.339	.562	0	1.477	.227	.01	5.717	.018 *	.05
Time × Condition × DSA	9.61	.002 **	.08	.348	.557	0	1.599	.209	.01	1.15	.286	.01
Time × ASA × DSA	.048	.826	0	.041	.841	0	1.477	.227	.01	1.467	.228	.01
Time × Condition × ASA ×DSA	.017	.898	0	.557	.457	.01	.911	.342	.01	1.824	.179	.02
Repetition × ASA	.013	.909	0	.319	.573	0	4.313	.04 *	.04	.055	.815	0
Repetition × DSA	.304	.582	0	4.312	.04 *	.04	2.602	.109	.02	1.116	.293	.01
Repetition × Condition × ASA	.069	.793	0	.001	.977	0	.538	.465	.01	.764	.384	.01
Repetition × Condition × DSA	.446	.506	0	.884	.349	.01	.193	.661	0	.178	.674	0
Repetition × ASA × DSA	1.628	.205	.01	2.202	.141	.02	.009	.923	0	.086	.77	0
Repetition × Condition × ASA × DSA	.009	.926	0	.125	.724	0	4.236	.042 *	.04	.35	.555	0
Time × Repetition × ASA	1.206	.274	.01	.313	.577	0	1.047	.308	.01	.226	.635	0
Time × Repetition × DSA	.855	.357	.01	3.598	.06	.03	.004	.947	0	.495	.483	0
Time × Repetition × Condition × ASA	.005	.946	0	.814	.368	.01	1.113	.294	.01	.858	.356	.01
Time × Repetition × Condition × DSA	.437	.510	0	.653	.421	.01	5.015	.027 *	.04	.028	.867	0
Time × Repetition × ASA × DSA	.012	.914	0	2.689	.104	.023	.62	.433	.01	.188	.666	0
Time × Repetition × Condition × ASA × DSA	.384	.536	0	.002	.967	0	.743	.391	.01	1.026	.313	.01

Note. The degree of freedom (*df*) for all statistics listed in the table is (1, 115). Significant results are marked with * ($p < .05$), ** ($p < .01$), and *** ($p < .001$).

Travel Distance. Participants' defensive trait (DSA) altered their travel distance shown in the three-way interaction between DSA, time, and condition, and DSA, $F(1, 115) = 9.61$, $p < .01$, $\eta_p{}^2 = .08$. Difference in travel distance was more salient in the survival condition among individuals with low DSA, exhibiting facilitated locomotion during the nighttime (M = 1408.8, SE = 96.41) than the daytime (M = 997.89, SE = 66.7). On the other hand, those with high DSA showed greater difference in travel in the free exploration condition, exhibiting facilitated nighttime travel (M = 1402.29, SE = 112.81) and relatively inhibited daytime travel (M = 1045.87, SE = 78.04; See Figure 8).

Figure 8.

Travel Distance across DSA × Time × Condition

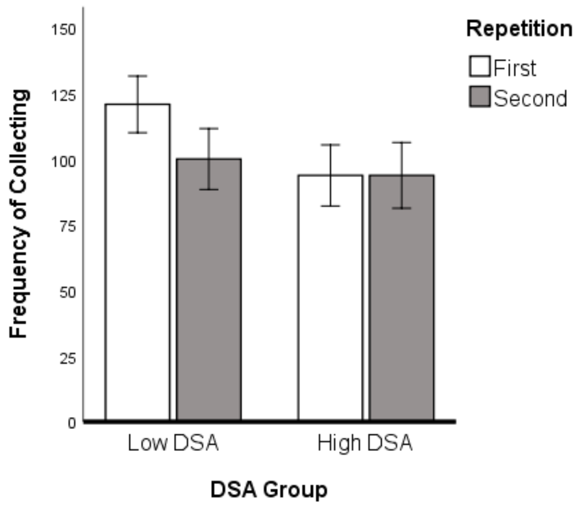


Note. Error bars represent the 95% confidence intervals around the values.

Collecting. DSA also moderated changes in collecting behavior over repetitions, $F(1, 115) = 4.312$, $p < .05$, $\eta_p{}^2 = .04$. Overtime, the low DSA group started with facilitated collecting during the first half of gameplay (M = 120.81, SE = 5.44), which was later inhibited (M = 98.98, SE = 5.86). For those with high DSA, collecting behavior was relatively inhibited compared to the low DSA group (M_{first} = 93.76, SE_{first} = 5.87; M_{second} = 93.76, SE_{second} = 6.32), and the trend did not change much over repetitions (See Figure 9).

Figure 9.

Collecting Frequency: DSA × Repetition Interaction

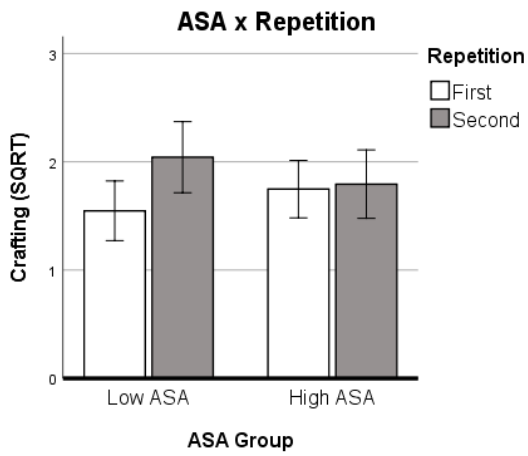


Note. Error bars represent the 95% confidence intervals around the values.

Crafting. Repeated measures ANOVA found significant moderations of both ASA and DSA on crafting behavior. According to the interaction between ASA and Repetitions, while individuals with high ASA had stable amount of crafting behavior overtime, those with low ASA started with relatively low instances of crafting which later increased, $F(1, 115) = 4.313$, $p < .05$, $\eta_p{}^2 = .04$.

Figure 10.

Crafting: ASA × Repetition Interaction

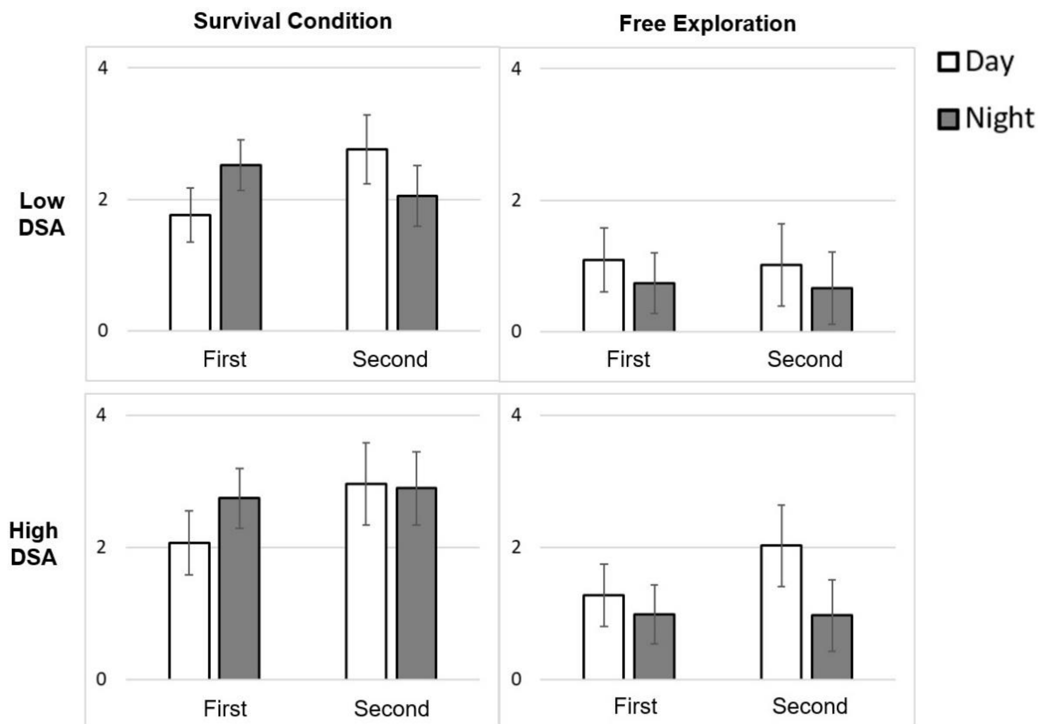


Note. Error bars represent the 95% confidence intervals around the values.

There was a four-way interaction effect between DSA, condition, time, and repetition, $F(1, 115) = 5.015$, $p < .05$, $\eta_p{}^2 = .04$. As shown in Figure 11, DSA did not inhibit crafting behavior with presence of nighttime threat. Instead, high DSA increased overtime frequency of crafting, especially during the high-threat context (i.e., second night in the survival condition) compared to the low DSA group. Although overall crafting frequency was low in the free exploration condition, those with high DSA crafted more items than the low DSA group, especially during the second day (See Figure 11).

Figure 11.

Crafting: DSA × Condition × Time × Repetition Interaction

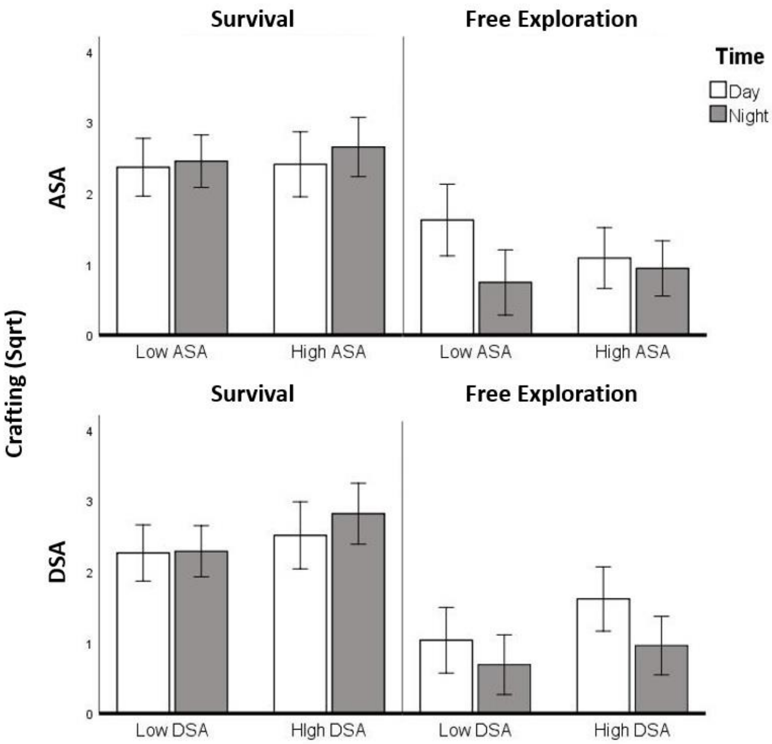


Note. Error bars represent the 95% confidence intervals around the values.

Another four-way interaction involving ASA and DSA found that both ASA and DSA led to facilitated crafting behavior with nighttime threat in the survival condition, $F(1, 115) = 4.236$, $p < .05$, ${\eta_p}^2 = .04$. In the free exploration condition, however, low ASA shaped facilitation of crafting activities during the daytime compared to the nighttime. This daytime facilitation was more salient among the high DSA group, indicating that ASA and DSA function differently with presence or absence of threat.

Figure 12.

Crafting: ASA × DSA × Condition × Time Interaction

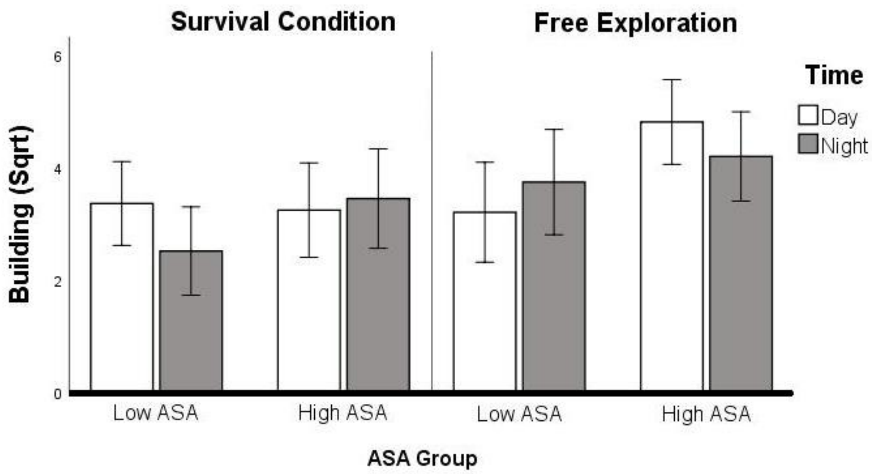


Note. Error bars represent the 95% confidence intervals around the values.

Building. The three-way interaction between ASA, time, and condition showed that ASA significantly moderated building behavior in response to different threat levels across conditions, $F(1, 115) = 5.717$, $p < .05$, $\eta_p{}^2 = .05$. In support of H2a, overall building frequency was higher for the free exploration condition than the survival condition, and the highest building activity was observed among the high ASA group during the daytime in the free exploration condition. Those with high ASA built more during the daytime in the free exploration condition than the nighttime, while the low ASA group who played the same condition built more during the nighttime. Interestingly, this trend was the opposite for the survival condition; high ASA resulted in more building during the nighttime in the survival condition than the daytime, whereas low ASA led to less building behavior in the nighttime.

Figure 13.

Building: ASA × Condition × Time Interaction



Note. Error bars represent the 95% confidence intervals around the values.

How Does Trait Motivational Reactivity Modulate Defensive Behavior?

Table 7 lists all results involving the effects of ASA and DSA on participants' defensive behavior (hiding and killing).

Table 7.

Test Statistics for Modulation of Trait-motivational Reactivity: Defensive Behavior

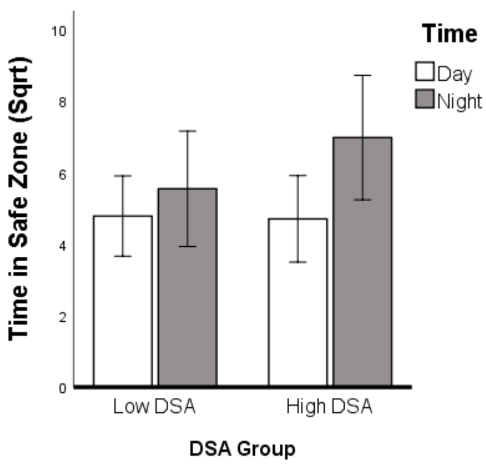
Effect	F	p	$\eta_p{}^2$	F	p	$\eta_p{}^2$
		Hiding			Killing	
Time × ASA	.004	.947	0		-	
Time × DSA	4.128	.044 *	.04		-	
Time × Condition × ASA	.178	.673	0		-	
Time × Condition × DSA	.863	.355	.01		-	
Time × ASA × DSA	.88	.355	.01		-	
Time × Condition × ASA ×DSA	4.126	.045 *	.04		-	
Repetition × ASA	.336	.563	0	3.327	.07	.03
Repetition × DSA	1.077	.302	.01	.996	.32	.01
Repetition × Condition × ASA	.091	.763	0	4.292	.04 *	.04
Repetition × Condition × DSA	.679	.412	.01	2.398	.124	.02
Repetition × ASA × DSA	2.428	.122	.02	.03	.864	0
Repetition × Condition × ASA × DSA	.298	.586	0		-	
Time × Repetition × ASA	3.621	.06	.03		-	
Time × Repetition × DSA	.036	.849	0		-	
Time × Repetition × Condition × ASA	3.342	.07	.03		-	
Time × Repetition × Condition × DSA	.093	.761	0		-	
Time × Repetition × ASA × DSA	.029	.866	0		-	
Time × Repetition × Condition × ASA × DSA	.222	.638	0		-	

Note. The degree of freedom (*df*) for all statistics listed in the table is (1, 115). Significant results are marked with * ($p < .05$), ** ($p < .01$), and *** ($p < .001$).

Hiding. Consistent with H2b, facilitation of hiding under threat (i.e., nighttime) was more salient among the high DSA group (M = 6.98, SE = .88) than the low DSA group (M = 5.55, SE = .81). Daytime hiding was relatively stable across both DSA groups, $F(1, 115) = 4.128$, $p < .05$, $\eta_p{}^2 = .04$ (See Figure 14).

Figure 14.

Hiding: DSA × Time Interaction

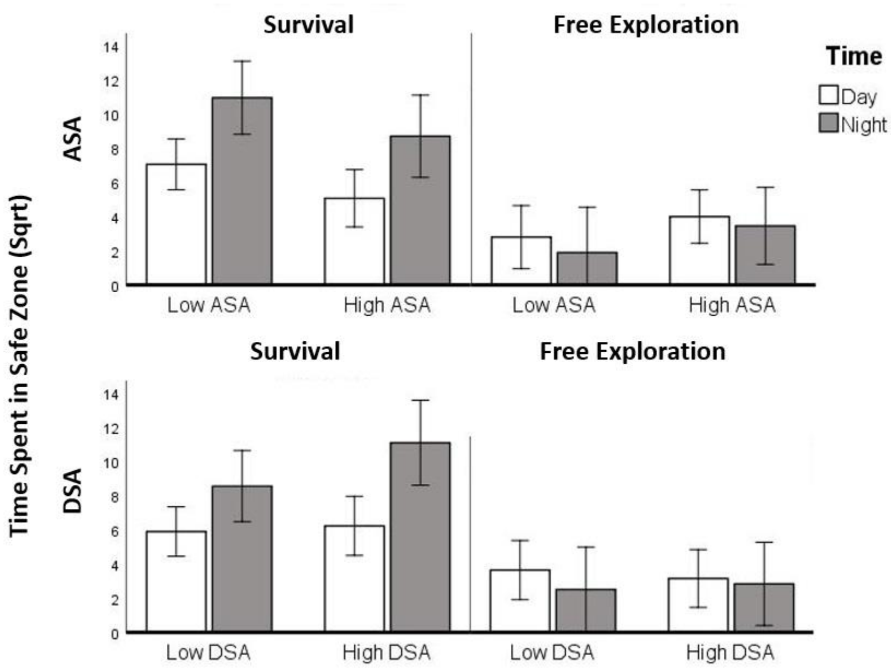


Note. Error bars represent the 95% confidence intervals around the values.

Furthermore, both ASA and DSA were involved in the four-way interaction with time and condition, $F(1, 115) = 4.126$, $p < .05$, $\eta_p{}^2 = .04$. As Figure 15 shows, ASA and DSA yielded distinctive hiding patterns in the survival condition. Specifically, ASA reduced hiding time while DSA increased hiding time, particularly with higher threat during the nighttime. With the absence of threat in the free exploration condition, both ASA and DSA displayed similar patterns that did not change much across conditions.

Figure 15.

Hiding: ASA × DSA × Time × Condition Interaction

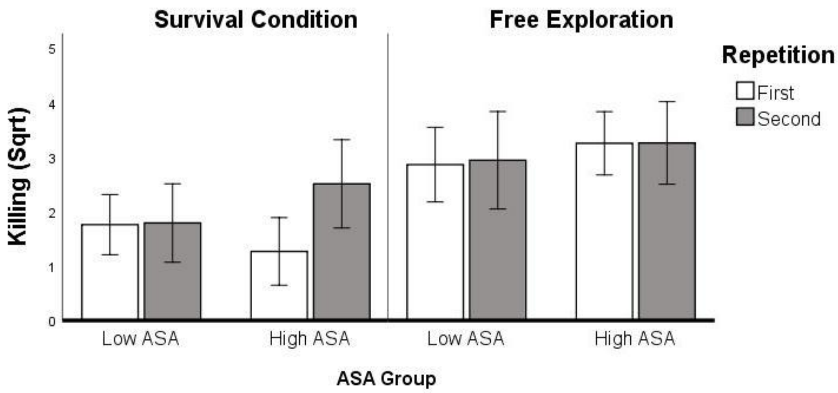


Note. Error bars represent the 95% confidence intervals around the values.

Killing. Although killing was categorized as defensive behavior, the three-way interaction between ASA, condition, and repetition found that ASA was particularly relevant to facilitating combats and killing behaviors, $F(1, 115) = 4.292$, $p < .05$, $\eta_p{}^2 = .04$. Overall, killing frequency was the highest among the high ASA group in the free exploration condition and inhibited among the low ASA group in the survival condition. Additionally, in the survival condition, individuals with high ASA exhibited overtime facilitation of killing activities in the second half of gameplay (See Figure 16).

Figure 16.

Killing: ASA × Condition × Repetition Interaction



Note. Error bars represent the 95% confidence intervals around the values.

DISCUSSION

This study investigated how users' self-guided behavior during gameplay develops by adaptively responding to motivational relevance of the environment. A virtual environment was created which systematically varied the level of threat (enemies and hunger) and resources (building materials and food items) available to players. By examining behavior from basic to advanced actions during the course of two days in game time, analyses found distinctive behavioral patterns over time across individuals with different trait motivational reactivity. Results overall suggest that players develop behavioral patterns in a way to gain in-game benefits by approaching and collecting resources and survive by avoiding or removing threats in the environment. However, facilitation of approach behavior was not always guided by the absence of threat; instead, different combinations of in-game contexts led to approach behavior including traveling, collecting, and crafting. Defensive behavior also showed different patterns in terms of fighting versus hiding. Furthermore, as expected, trait-based motivational reactivity significantly moderated responses to the game environment, clarifying the distinction between two motivational orientations—approach and avoidance. In the following section, I discuss specific results and their implications for understanding player behavior as motivational responses within a constrained framework.

Interpretation of Findings

Motivational Orientations for Exploratory Locomotion. Although basic locomotion and exploratory actions were categorized as approach behavior, participants' travel distance was not systematically inhibited in the threatening environment or facilitated in the absence of threat. Instead, travel distance increased in the second day-night cycle, indicating the expansion of exploration boundaries overtime. The overtime increase in travel distance can indicate both facilitated exploration under low threat (approach motivation) or running away from the threat (defensive motivation). The distinction between these two motivational orientations becomes clear by looking at the moderating effect of individuals' trait-motivational reactivity. Participants in the low DSA group traveled farther during the nighttime when playing in the survival condition, whereas travel was more facilitated for the high DSA group in the free exploration condition. This result suggests that for those with highly defensive trait motivational reactivity, travel was facilitated with the absence or low level of threat. For those with low defensive trait, on the other hand, the presence of threats increased traveling, indicating approach toward threats. Therefore, facilitation of locomotory exploration depends on how individuals' defensive trait motivation reacts to presence or absence of threat.

Operation of Approach Motivation for Collecting and Crafting. Unlike travel behavior, patterns in collecting and crafting behavior were clearly shaped by the game conditions. Both collecting and crafting behaviors were critical for challenges in the survival mode, such as harvesting berries and crafting meals to nourish the player character or recover the health level. Collecting could be considered as a more fundamental and simple behavior than crafting. Collecting simply required clicking an object or moving closer to spawned items. Crafting required ingredients from collected items and knowledge to use the workbench and recipes, many more clicks, and a specific sequence of events. Results showed that participants overall collected and crafted more items in the survival condition than the free exploration condition. Survival mode players tended to collect more items during the first day and crafted more items in the later part of the game, exhibiting greater refinement in the use of game features over time. On the other hand, participants in the free exploration condition collected and crafted less items compared to the survival mode, and frequencies of these activities also decreased over time. This trend indicates approach behavior can be facilitated with perceived needs or tasks, such as survival challenges and the need for creating and using items.

While collecting seemed more evidently guided by the game environment than trait motivations, individuals with low DSA engaged more in crafting during the early phase of the gameplay which decreased in the later phase. This implies that highly defensive individuals were more cautious in actively looking for resources in a novel environment, resulting in the early inhibition of approach behavior (collecting).

Regarding crafting behavior, ASA was overall involved in facilitating early phase crafting as well as facilitated crafting under threat (i.e., nighttime in the survival condition). Notably, high DSA also resulted in increased crafting with presence of threat similar to the functioning of high ASA. That said, facilitation of crafting behavior may be induced with coactive states when both appetitive and aversive motivational systems are activated. Because crafting could lead to creation of both nutritional resources (e.g., food) and defensive objects (e.g., weapons), future investigation on the number and types of crafted items will further clarify the motivational direction underlying crafting behavior.

Facilitation of Building as Approach Motivation. The observed pattern for building as approach behavior was somewhat different from collecting and crafting. Building behavior in a sandbox game can be thought as a creative and advanced activity that takes longer time and requires a series of different actions (e.g., selecting and moving a block, individual planning, and placing). Although building activities increased over time especially among experienced gamers, facilitation of building in terms of in-game conditions was moderated by trait-motivational reactivity—ASA.

In our results, free exploration with no functional threat led to more instances of building behavior (piling blocks) among the high ASA group, especially in the favorable environment during the daytime. This indicates that high ASA coupled with a threat-free situation promotes approach behavior in an advanced level, in line with study predictions. On the other hand, the low ASA group during free exploration and high ASA with survival challenges showed increased building activities during the nighttime, implying potential negotiation between individual ASA level and perceived safety/threat in the virtual world. That is, ASA may shape building activity under threat based on the need to build a defensive structure while building without threat may be guided by various individual goals not particularly associated with perceived threat.

Two Directions of Defensive Behavior. Regarding defensive behavior, different results were observed for hiding versus fighting (killing). For hiding, large effects of conditions and the day-night cycle demonstrated that the survival-relevant context and nighttime threat constrained players to find and stay in a shelter. Of note, hiding behavior occurred even when the game did not contain an implicit goal to survive (i.e., free exploration mode). As predicted, hiding was evidently moderated by defensive motivational trait, evidenced by increased hiding time in threatening situations among the high DSA group. ASA also led to variations in hiding time, demonstrating that individuals with high approach tendency spent less time in the safe zone even in encounter with nighttime threat.

On the other hand, fighting behavior was facilitated in the free exploration versus survival condition. This implied that in the absence of functional threat, individuals may engage in fighting (killing) under approach motivation rather than defensive motivation. In fact, killing was more related to ASA rather than DSA, evidenced by increased killing activities among the high ASA groups. This result indicates that in low risk survival-relevant contexts like video games, fighting may be guided by appetitive motivational activation rather than aversive activation.

Taken together, the results focusing on the role of motivational relevance reveal how opportunities and threats in the game environment guide player behavior. Importantly, approach-related behavior seems to grow more complex (crafting, building) or wider in range (travel) over time. Regarding defensive behavior, hiding was firmly stable avoidance behavior under threatening situations while fighting (killing) seems to develop as approach behavior in the game. Overall, although three-way or four-way interaction effects are often hard to interpret, the behavioral patterns shown in various interaction effects are clearly in line with theoretical predictions regarding ASA and DSA in response to presence or absence of threat. This has implications for both game designers and researchers who seek to understand motivational processes in dynamic game environments.

Implications for Media Design and User Research

Using player-generated behavioral data to examine psychological constructs has been of great interest among game designers and user experience researchers (Renaud & Gray, 2004; Sifa, Drachen, & Bauckhage, 2018). Sandbox and open world games offer a wide variety of potential behaviors so that users find motivations for gameplay from learning and adapting various ways to enjoy the games instead of following a strict sequence of manifest challenges (Squire, 2008). With these increasing degrees of freedom and player autonomy, understanding the relationship between player motivation and their use of game affordances is important to better explicate the negotiation of player goals as situated within game affordances.

By building this study on both understandings of game affordances and motivational relevance, we are able to explain what may appear to be idiosyncratic player behavior using parsimonious concepts which are nevertheless predictive of behavioral trends. Given that player experience consists of actions they perform in the game environment, players' motivational responses that either facilitate or inhibit learning and use of different game affordances can change the quality of individual gameplay. Results from this study suggest that varying levels of motivationally relevant features of the game altered frequency of performed behaviors in a predictable manner. From our data, it appears that players begin as primarily reactive to the environment, shown by the increased collecting and crafting activities with survival challenges or increased hiding under threat. By observing and examining frequency and duration of various player behavior in early phase of gameplay, designers and user researchers may better predict the player's subsequent behavior in an advanced level.

This study also demonstrated the importance of individual differences in motivational traits in guiding qualitatively different player behavior in response to different motivational contexts. Individuals' ASA and DSA levels are motivational reactivities that are fundamental to all behavioral responses people show to both mediated and real-life experiences. The different behavioral patterns from varying ASA and DSA groups observed in this study imply that players explore, learn, and experience the game environment as if infants were learning and developing in the real world. In the process of motivated learning and exploration, individuals with highly defensive traits are likely to engage with various activities in low-threat contexts as their behavior is inhibited or focused on aversion (e.g., hiding) in the threatening situation. For those with highly appetitive motivational trait, survival challenges or presence of enemies will lead to facilitated activities in various levels, such as collecting, crafting, and fighting.

Overall, the results from this study shows support for the understanding of player behaviors in games as an ongoing, dynamic negotiation between player motivations and in-game affordances in a novel but generalizable fashion. These findings can enrich both our understandings of in-game behavior as well as the psychological underpinnings of behavior in virtual environments.

Limitations and Future Direction

These results are an initial exploration of a rich data set. Although the analyses on aggregated behavioral data across variable in-game contexts revealed significant findings on behavioral patterns of players, the results did not clearly identify the underlying motivational directions for some levels of behavior corresponding to hypotheses, such as travel distance, crafting, and fighting. This may be because players can further break down their behavior into different motivations or goals beyond broadly structured in-game affordances. For example, crafting activities can be further distinguished in terms of what items were crafted as underlying goals for crafting many food items would be different from those for crafting many weapon items. Future analysis should involve unpacking player behavior based on fine-grained behavioral data though the aggregated results presented here show overall trends which best speak to the theoretical intersection of motivation and in-game affordances. Further analysis of player motivations via qualitative exploration of their interview responses is forthcoming and will add nuance to these quantitative results.

In addition, 40 minutes of gameplay with two repetitions could be too short to capture learning and development of advanced activities and goals. Creative activities like building often require high skills level and involve long-term planning. Difference between short-term goals such as mining to collect certain ingredients and long-term goals like building a large-scale village is also quite large. Indeed, previous studies using Minecraft investigated user responses or effects in a relatively longer time span, such as several months (Nebel, Schneider, & Rey, 2016). That said, despite the research focus on initial exploration and responses to the game environment, results from this study are limited to relatively short-term learning and goals. Future studies involving a longitudinal design, or a field study setting would be beneficial for explaining behavioral development of players in terms of long-term effects.

Moreover, using behavioral data based on action frequencies often makes it difficult to achieve normality of data. In fact, all parameters from this study had positively skewed distributions which led to violation of normality assumptions with the raw data. Although this study transformed the skewed data to place the values on an acceptable range, future studies investigating relatively long-term effects will likely involve greater skewness in distributions, thus should carefully treat outliers or involve non-parametric tests.

The results from this study also implied that thresholds for perceiving threats, boredom, or enjoyment in the same game environment would be different depending on players' motivational traits. For example, those with high DSA may be more likely to learn and engage with advanced game affordances with a low threat context. On the other hand, those with high ASA may try out most game affordances in early stage of gameplay and are likely get bored without increasing threats or novel challenges. That said, future studies may identify the points at which different individuals' threat habituation starts, and how the habituation relates to sustained gameplay.

Future research can also benefit from integrating self-determination theory (SDT) to understandings of approach and avoidance motivation to better explain formation of higher-order motivations through media use. According to SDT, Individuals are most self-determined – that is, intrinsically motivated to be engaged in a behavior – when they have the locus of control (autonomy) and a sense of competence and effectance in the activity (Deci & Ryan, 1985; Ryan & Deci, 2000). Series of studies on video game motivation using SDT have demonstrated that perceived autonomy, competence, and relatedness (feeling of connection with others) were associated with increased enjoyment of games and intentions for future gameplay (Ryan et al, 2006). That said, different approach and avoidance behaviors users perform during gameplay or media use may also be fundament for perceiving autonomy and competence, which in turn leads to self-determined higher-order motivation and behavior. Moreover, although autonomy for playing games can be high given the voluntary aspect of gameplay, different games mechanics offer varying levels of autonomy, such as the choice over behavioral sequences, movement, and strategies. In this sense, player interactions with specific elements of the game environment can mediate subsequent perception of autonomy. That said, future research can investigate how approach and avoidance responses during gameplay guides development of self-determined behavior overtime.

Finally, future studies should present more exploratory analyses to take advantages of the descriptive nature of tracking data. Focusing on confirmatory analyses and hypothesis testing allows this study to explain game behavior in terms of motivational processes, but data driven analytical approaches will further clarify stability and variability of user behavior within and across individuals.

APPENDICES

APPENDIX A

Game Design

Basic game elements, core mechanics, and graphics of the game are developed to simulate a commercially available videogame, Minecraft (Mojang, 2009). This study simplified, altered, or added specific elements so that the game can serve as an experimental stimulus.

Game Modes

Survival mode. The main goal is to survive in the game environment by finding resources, and crafting and building objects that increase chances to survive. Players will have threatening encounters that may result in death of the player character, such as loss of energy from hunger and loss of health due to attacks from creatures.

Free Exploration Mode. The game environment, available resources, and creatures are visually the same with the survival mode. In the free exploration condition, player character's health and energy level are set to 100% and will not incur any damage or energy loss.

Game Space and Time

Overall Environment. A temperate biome consisting of plains, hills, trees, plants, and animals is simulated using procedural generation algorithms. The environment consists of 500 ×500 ×500 blocks that can be mined to gain material resources, such as stone, wood, and ore. The environment is consistent across all conditions and participants.

Time in Game. A day-night cycle is 20 minutes long, divided into 10 minutes in day (bright) and 10 minutes in night (dark). Creatures spawn in the nighttime at 6 p.m. and disappear in daytime at 6 a.m. in the game.

Tutorial session. A separate environment that only has daytime is used for the tutorial session. The starting position of the tutorial map contains a crafting workbench so that the participant can practice controls for crafting. Tutorial session also starts with three of each basic resource item (wood, stone, berry) and basic tools (shovel, workbench, torch). The actual non-tutorial game session only starts with a shovel, workbench, and torch and no resource item.

Game Affordances: Available Actions

Walking. This action allows the player character to make translational movements on x, y coordinates in the game environment. Control uses W, A, S, D and Spacebar key.

Running. Movement speed for running is two times faster than walking. Running control uses Shift key while walking.

Spawning Objects. This action, when performed via mining or foraging, results in generation of an object that is available to pick up.

Mining. Mining produces a material block by left-clicking the mouse. Mining results in a removal of original block and generates a smaller block item (ore, stone, or wood) that can be picked up.

Foraging. Players can yield raw food items (berry) from tree or bush objects by left-clicking the mouse.

Collecting. A resource item (material or food) can be picked up and collected in the player inventory by moving close to the object.

Consuming Object. The player can eat meal or food items by opening the inventory and double-clicking an item.

Equipping. Weapon or tool items can be equipped when the player opens the inventory and double-clicking a weapon item.

Throwing an Object. When an equipped item is not a material block, the player may through an item by right-clicking at the targeted spot. Throwable items include any non-material blocks, such as berries, paints, bombs, and tools.

Attacking. The player can attack a creature or destroy an object by left-clicking the mouse on the object.

Crafting Object Using Recipes. The player can open the recipe window by pressing R key. The recipe window shows both the player inventory and ingredient boxes where the player can add ingredient items from the inventory. An object will be crafted if correct items are placed in the ingredient boxes by and the player clicks the "Create" button in the window. Crafting will fail if placed items do not match any available recipes.

Piling a Block. the player can pile material blocks to build a structure by bringing them from the inventory (Tab button), clicking a block, and releasing it using the right-click to the spot they want to place it.

Interface

Inventory. The player can open the item inventory by pressing tab button. The inventory window shows stacks of objects the player has picked up and collected. Participants can see the description of each item by hovering the mouse cursor on item icons. The inventory can be closed by pressing tab button again.

Recipe window. Pressing R button opens the list of available recipes in the game. Each recipe shows the icon and name of craftable objects and required ingredients to craft them. Recipes for non-hidden items show the entire ingredient icons while those for hidden items show questions marks ("?") in the ingredient boxes.

Researcher Interface/Debug Mode. Debug features are enabled when the researcher mode is on by pressing F1. Two debug features include a) spawning an enemy for testing (X key) and b) enabling/disabling flying mode (F key).

Items

Raw Items

Material Blocks. Block items can be used to build a structure or craft a tool item. Three kinds of blocks are available in this game: a) wood (obtained from tree trunks), b) stone (obtained from rocks), and c) ore (obtained from ore blocks).

Resources. A resource object can be gathered by foraging. Resource items can be used to nourish the player's health and satiety levels or for crafting. Three kinds of items are available for foraging/harvesting: a) berry (obtained from tree leaves and bushes), b) paint (obtained from colored grass and flowers and can be used to paint a block), and c) leaf (obtained from tree leaves)

While berries can be eaten as raw as well as ingredients, leaves can only be used as ingredients for crafting (e.g., ingredient for a salad item).

Craftable Items

Players can craft an item using a workbench. Three workbench items are provided in the player inventory by default. In order to use the workbench, players need to place it on the ground. Once placed, the workbench stays in the placed location unless the players displace it by left clicks.

Meal. When eaten, meal items increase hunger and health levels. Cooked meals are more effective than eating raw berries in terms of the amount of energy and health points to be restored. Four types of meal items are craftable with following ingredients:

Fruit juice: berry + berry

Soup: berry + stone

Salad: berry + wood

Potion: flower + wood (hidden recipe)

Torch. When equipped or placed on a surface, a torch lights up the area around it. A torch can also be equipped to damage the monster. Ingredients to craft a torch are two wood items.

Paint. A paint item can be used to add a color to the piled block by clicking the wheel button on the target block. Three kinds of colors can be crafted or foraged from flowers: red, blue, and green.

Weapons and Tools. Weapons carry more damage than bare hands when hitting the monsters. Although a shovel can also be used as a weapon, the damage it carries less damage than weapons.

Spear: ore + wood

Sword: ore + iron

Iron Shovel: stone + wood

Bomb: ore + ore (hidden recipe)

Safe Zone

The safe zone is a square-shaped area surrounding the character's stating point (about five meters diameter). The safe zone is visually distinguished from the field, surrounded by blue fences and lights. Creatures cannot get into the safe zone.

Threats in Game

Monsters. Monsters chase and damage the character. At 6 p.m. in the game time (beginning of the night), monsters randomly appear the area around the player within 35-50 meters from the player). A monster will appear every five seconds but will not exceed 10 around the player. When the player is within ten tiles from a monster (about ten meters), the monster starts to chase the player. The monster will stop chasing the player if the player moves away from them (farther than ten tiles).

Hunger System. Players start with 100 energy and satiety levels in both modes. In the survival mode, the energy level decays by 10 points every 40 seconds. The health level decreases by 15 when attacked by a monster. The lost energy or health level can be restored by intaking berry, meals, or potion items. In the free exploration mode, the energy and health level are fixed at 100% and will not decrease.

Death. The player character will die when either the energy or health level becomes zero due to hunger or damage from monsters. When dying, the player reappears at the starting place (i.e., safe zone) with 20 percent of energy and health level restored.

End of Gameplay

Upon the completion of the participant’s task to spend 40 minutes in the environment (i.e., end of the second night in the game), a message pops up to indicate that the session is over, and the system stops collecting data. The researcher then exits the game by pressing Alt + F4 key. Even if the session ends before spending two full day and night cycles, data will still be generated up to the exit time.

APPENDIX B

Structure of Dataset

Character Status Log

This log recorded player character's status every .1 second. The log included timestamp, coordinates of player location in the map (x, y, z), rotation of the player's character (x, y, z), health level, energy level, whether the character was being chased by a monster, distance from the closest monster if when chased, and equipped tool or weapon.

Event Log

The event log focused on types of all actions performed by the player. The following action categories are defined and logged: hitting a voxel, breaking a voxel (mining), collecting, consuming, crafting, building, attacking, being attacked, and dying. All these actions are logged with timestamps, spatial coordinates of the target object, and outcome of the action (e.g., crafted item, collected item, killed monster).

Aggregate Data Log

The aggregated log was generated based on action categories in the event log. Action frequencies or time spent performing certain actions were aggregated and logged according to in game time conditions and repetition (i.e., first day, first night, second day, second night). All behavioral parameters available in the aggregated log are listed below:

Travel Distance

The Number of Blocks Mined

The Number of Food Items Created

The Number of Blocks Used

The Number of Blocks Stacked (Building Frequency)

The Number of Consumed Food Items

The Number of Items Crafted (Crafting)

Frequency of Failed Crafting

The Number of Weapons Created

Frequency of Weapon Use

Frequency of Death

Amount of Damage Taken

The Number of Monsters Killed (Killing)

Time Spent Walking

Time Spent Running

Time Spent Chased by Monsters

Time Spent in Safe Zone (Hiding)

Time Spent with Hunger

The Number of Items Collected (Collecting Frequency)

The Number of Berries Collected

The Number of Wood Blocks Collected

The Number of Stone Blocks Collected

The Number of Ore Blocks Collected

The Number of Paint Items Collected

The Number of Leaves Collected

Health Points Gathered

Health Points Recovered

Energy Point Gathered

APPENDIX C

Survey Instruments

Pre-gameplay Survey Items

Demographic information

What gender do you identify yourself as? (Male, Female, Other)

What is your age? Please type a number.

Previous Videogame Experience

1. Have you played any videogame? (Yes, No)
2. In a typical week, about how many days do you spend at least 30 minutes playing a videogame?
   a. 0-1 day
   b. 2-3 days
   c. 4-5 days
   d. 6-7 days
3. Would you consider yourself to be a…
   a. Casual Gamer (i.e. you dabble in games but in short sessions or infrequently)
   b. Core/Mid-Core Gamer (i.e. you regularly play video games but are not super serious or competitive)
   c. Hardcore Gamer (i.e. you have high-end equipment and play seriously or competitively)

***Motivational Activation Measure* (Lang et al., 2011)**

Instruction. In this section, you are going to look at pictures. You can view each picture as long as you like. When you are done viewing a picture, click the "Continue" button. After looking at each picture, you will be asked to rate, on 3 scales, how you felt while you were looking at it.

First, we ask you to rate how aroused you felt on a 9-point scale where 1 is not at all aroused, not at all excited, not at all awake and 9 is extremely aroused, excited, awake.

Next, we will ask you to rate both how negative and how positive you felt while viewing each picture. Sometimes the negative rating scale will come first, and sometimes the positive scale will come first. We want you to rate how negative and positive you felt separately. So you can feel both negative and positive or just negative or positive.

You will rate how positive you felt on a 9-point scale where 1 is not at all positive, not at all happy, not at all pleased and 9 is extremely positive, happy, pleased.

You will rate how negative you felt on a 9-point scale where 1 is not at all negative, not at all unhappy, not at all annoyed and 9 is extremely negative, unhappy, annoyed.

Participants are next presented with 41 pictures from the International Affective Pictures System.

Player Motivation Typology (Tondello, Arrambide, Ribeiro, Cen, & Nacke, 2019)

Instruction: Now, you will read several statements about your behaviors and experiences when you play games. After reading each statement, please indicate the level of your agreement to the statement on a 7-point scale from Strongly Disagree to Strongly Agree.

T1 . I like to build or create new things or objects or characters in games.

T2. I like games with unique art styles.

T3. I often feel in awe with the landscapes or other game imagery.

T4. I like to customize how my character looks in a game.

T5. I like it when games have an element of exploration.

T6. I care more about gameplay than about graphics and sound. (R)

T7. The quality of the graphics and sound are really important for my appreciation of a game.

T8. I like to spend some time exploring the game world.

T9. I like it when games look unique or vibrant.

T10. I usually choose gear, weapons, or other game items based on what they look like.

I1. I like games which make me feel like I am actually in a different place.

I2. I enjoy complex narratives in a game.

I3. I like games that allow me to make decisions over the story.

I4. I like games with detailed worlds or universes to explore.

I5. I like it when I can be someone else in the game.

I6. I like games that pull me in with their story.

I7. I usually skip the story portions or the cutscenes when I am playing. (R)

I8. I feel like storytelling often gets in the way of actually playing the game. (R)

I9. Story is not important to me when I play games. (R)

I10. I like it when playing a game makes me lose track of time.

Behavioral Inhibition System/Behavioral Activation System (BIS/BAS; Canver & White, 1995)

Instruction: On a 4-point scale from Strongly Disagree to Strongly Agree, participants will respond to the following questions.

BIS Behavioral Inhibition.

If I think something unpleasant is going to happen I usually get pretty “worked up.”

I worry about making mistakes.

Criticism or scolding hurts me quite a bit.

I feel pretty worried or upset when I think or know somebody is angry at me.

Even if something bad is about to happen to me, I rarely experience fear on nervousness.

I feel worried when I think I have done poorly at something.

I have very few fears compared to my friends.

BAS Reward System.

When I get something I want, I feel excited and energized.

When I’m doing well at something, I love to keep at it.

When good things happen to me, it affects me strongly.

It would excite me to win a contest.

When I see an opportunity for something I like, I get excited right away.

BAS Drive.

When I want something, I usually go all-out to get it.

I go out for my way to get things I want.

If I see a chance to get something I want, I move on it right away.

When I go after something I use a “no holds barred” approach.

BAS Fun Seeking.

I will often do things for no other reason than that they might be fun.

I crave excitement and new sensations.

I’m always willing to try something new if I think it will be fun.

I often act on the spur of the moment.

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