Dissecting Play – Investigating the Cognitive and Emotional Motivations and Affects of Computer Gameplay[1]

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Abstract-**All games are cognitive learning environments. A cognitive approach to understanding games and gameplay emphasises the analysis and understanding of these learning functions and how game design features facilitate them. The experience of gameplay is one of interacting with a game design in the performance of cognitive tasks, with a variety of emotions arising from or associated with different elements of motivation, task performance and completion. Psychophysiological techniques provide empirical methods for investigating play that provide a foundation for developing plausible models of what those cognitive decision processes are, how they relate to design features and how emotions integrated with task performance lead to rewards of play, creating an experience of 'fun'.**

I. Introduction

Entertainment computer games have been very successful because of the highly engaging and immersive gameplay experiences that they create for players. Fun is the primary goal of entertainment game design. Game designers have long recognized games as cognitive learning environments ([7], [23]), although the systematic investigation of fun and its detailed relationship to learning processes are currently at an early stage of development. An immediate question is: what does it mean to refer to the systematic study of gameplay? In general, studying gameplay involved trying to extract different aspects of meaning in the experienced and observable behavior of gameplay. Semiotics is the study of signs, signification and sign systems, including how meaning is constructed and understood. Hence in a broad sense, it may be said that we are interested in the development of the semiotics of computer gameplay. In [26], it was suggested that it is possible to analyse the semiotic processes involved in gameplay in terms of a hierarchy of semiotic and symbolic complexity, for example and in order of increasing symbolic level and complexity:

- basic cognitive functions and emotional rewards associated with their operation (e.g. the generation of perceptions, recognition of patterns and gestalts, balance of attentive resources)
- task-oriented cognitive mechanisms (i.e. cognitive processes that map perceptions through decision processes to produce actions oriented towards *goals*)
- semiotic and symbolic constitution of the self
- semiotic and symbolic constitution of immediate social relationships
- semiotic and symbolic constitution of subcultural contexts
- semiotic and symbolic constitution of general cultural contexts

This constitutes a hierarchy in terms of the scope of meaning of objects and relations, from less conscious processes within the cognition of individuals, to large scale social and cultural constructs. We remain uncommitted on how the higher semiotic levels may epistemologically and ontologically determine the lower levels.

The hierarchy suggests that analyses of play could focus upon specific semiotic levels, or examine relationships between constructs at different levels. Systematic study also requires a clear methodology. Theories and methods from cognitive sciences, and especially from cognitive psychology, provide a foundation for these studies, based in the lower cognitive levels of the semiotic hierarchy. These levels appear to be amenable to the use of more scientific methods, as described and exemplified in this paper. As one moves up through the semiotic hierarchy, one moves further away from neurophysiological specialization and more towards generalized memory-(i.e. experience-)based, associative and abstract functions for which scientific methods become increasingly descriptive rather than explanatory, if applicable at all

II. Gameplay and Cognitive Science

[27], [28] present a theory of the underlying cognitive systems involved in gameplay based upon schema theory and attention theory. Schemas are cognitive structures that link declarative (or factual) and procedural (or performative) knowledge together in patterns that facilitate comprehension and the manifestation of appropriate actions within a context. While the taxonomical structures of semantic or declarative memory are comprised of object classes together with associated features and arranged in subclass/superclass hierarchies, the elements of schemas are associated by observed contiguity, sequencing and grouping in space and/or time [30]. Schemas can refer to declarative knowledge and taxonomical types with their features and relationships, and integrate these with decision processes. Schemas include *scripts* for the understanding and enacting of behavioural patterns and routines, a classic example being Schank and Abelson's [40] example of the *restaurant script* that includes a structure of elements for entering a restaurant, sitting down, ordering food, eating, conversing, paying the bill and leaving (etc.). Scripts, as structures used for both comprehension and behaviour generation, represent a structure of cognitive functions that may include cognitive resources, perceptual interpretations and preconditions, decision processes, attention management and responsive motor actions. *Story schemas*, are patterns representing a structure of understandable elements that must occur to make stories comprehensible. The presence of story schemas in the cognitive systems of storytellers, listeners, readers or viewers of stories allow stories to be told and to be comprehended, including the inference of missing information. If a story deviates too far from a known schema, it will not be perceived as a coherent story. Script and story schemas are concerned with structures of both space and time, while *scenes* are schemas representing spatial structures, such as the layout of a house or an area of a city.

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While schemas have been interpreted in many different ways, here a *gameplay schema* is understood as a cognitive structure for orchestrating the various cognitive resources required to generate motor outputs of gameplay in response to the ongoing perception of an unfolding gameplay experience. A gameplay schema is therefore the structure and algorithm determining the management of attentional and other cognitive, perceptual and motor resources required to realise the tasks involved in gameplay. Examples of types of gameplay schemas described by [27] include story scripts for understanding high level narrative structures designed into games, and scripts for the combative engagement of an enemy, exploring a labyrinth, interacting with a trader non-player character, and negotiating and carrying out quests.

Attention theory provides an account of the energetic resources available to cognition, together with principles for the distribution of energy (or attention) to the cognitive resources that use (or manifest) it. Attention theory addresses issues of attentional focus, management of attention (including attentional selection), and the allocation of cognitive resources to cognitive tasks. Ongoing research is addressing the question of the detailed operation of attentional mechanisms, including questions such as the degree to which attentional capacity is specific to specific cognitive resources (or modes) or sharable among resources according to demand, and the stage of processing of perceptual information at which perceptual information is selected for attentional priority. Schemas can be regarded as mechanisms or algorithms that, amongst other functions, determine the allocation of attention to cognitive tasks.

In the context of gameplay, attention and the operation of gameplay schemas is driven by hierarchical goals that set tasks for a player. Goals include those intended by designers and those created by players as allowed by a game design. A hierarchical decomposition of gameplay goals might at a high level include the completion of a game, which decomposes into the subgoals of finishing each of its levels, each of which in turn decomposes into goals of completing a series of game challenges (and other tasks invented by the player). We hypothesise that this hierarchical goal structure is mirrored in a hierarchical structure of schemas within a player's cognitive system, where a schema is an algorithm for completing a particular goal or subgoal.

Scientific method in cognitive science offers various criteria for assessing the usefulness of theories, conceived as their validity, including forms of validity described by [8]:

- *predictive validity* is achieved if the results of a test can be significantly correlated with a behavioral criterion at some time in the future. For example, a correlation might be found between the amount of time spent playing video games, and a later measured tendency towards aggressive tendencies, thoughts and behaviours (e.g., see [1]).
- *concurrent validity* is achieved if the results of a test can be significantly correlated with a behavioral criterion measured at the same time as the test.
- *content validity* concerns whether test items actually sample all phenomena of interest. For example, if we wish to test the subjective quality of game experience via a questionnaire, then the questions may need to assess experiences of boredom, immersion and flow. If boredom is not accommodated, then bored players may be misinterpreted as being in immersed or flow states.
- *construct validity* concerns the correlation of measured quantities on scales with theoretical constructs.

Hence a schema theory of gameplay, or the theories of game enjoyment described below, must be validated in these terms if they are to be regarded as scientific.

III. THEORIES OF FUN IN GAMEPLAY

As argued by [28], this schema structure is fundamental to many aspects of the pleasures and motivating factors behind play, providing a cognitive framework for explaining the pleasures of gameplay, including:

- *effectance*, which is a basic feeling of empowerment created when an action of a player results in a response from the game system [22]. The cause-effect relationships underlying effectance are a fundamental premise of goal-oriented schemas for action.

- *closures* at different hierarchical levels (as described by [17]), where a closure is interpreted here as the completion of the algorithm constituted by a play schema. Closures may involve completion of expected outcomes and resolution of dramatic tensions, corresponding to the completion of cycles of suspense and relief identified by [22].

- *achievement* of in-game tasks, which is rewarding due to the *displacement* of a player's identity into their character [17], this being a matter of *imaginative immersion* as described by [14]. Achievement oriented reward is a more elaborate form of reward than closure, since it is associated with the fictional meaning of specific goals.

- achievement of a sense of *flow* [10] in gameplay, this being a state of being totally absorbed in meeting a constantly unfolding challenge. Here we hypothesise that flow follows from details of challenge-specific schema execution.

- more complex forms of enjoyment in game tasks regarded as *episodes* [22] following from imaginative displacement into the game world. Enjoyment within episodes may include the excitement of possible action, the pleasures of curiosity and discovery, the pleasures of experiencing negative emotions of suspense followed by the transference of arousal to an ecstatic experience when the challenge creating the anxiety of suspense is overcome, and enhanced self-esteem. Schemas offer greater discrimination of the pleasures involved in episodes by allowing different forms of episodes to be modelled as different schema patterns having a complex substructure with corresponding emotional effects (e.g. different scripts for solving mysteries, combat, exploration, trading and quest negotiation).

- *escape* to an alternative reality provided by the fictional world represented by a game [22] and facilitated by imaginative displacement. Players have the pleasure of being able to experience new objects, actions, social interactions and experiences at no risk. These vicarious experiences can help players to cope with felt frustrations and deficiencies in their everyday lives, a process both of catharsis and of perception of increased competence and relevance. Schemas provide the foundations for comprehension of the events within the fictional world and provide mechanisms for projection of the player's sense of self into a fiction.

Schema theory therefore has the potential to provide both an explanation of the decision and operational processes underlying gameplay and an explanation of the detailed reward and motivation factors behind play. Validating this potential requires detailed study of play resulting in the development of empirically validated hypotheses about the detailed structure and functionality of gameplay schemas. Detailed study requires measurement techniques, which can include psychophysiological methods and technologies.

IV. PSYCHOPHYSIOLOGICAL RESEARCH

Emotions are a vital part of the game experience, motivating the cognitive decisions made during gameplay. *Psychophysiological research* suggests that at least some emotional states can be quantitatively characterized via measurement of physiological responses. Specific types of measurement of different responses are not *per se* trustworthy signs of well-characterized feelings ([3], [5]); a cross-correlation of measurements is fundamental to discovering the emotional meaning of different patterns in the data. A many-to-one relation between psychological processing and physiological response [4] allows for psychophysiological measures to be linked to a number of psychological structures, e.g., attention, emotion, and information processing. Using a response profile for a set of physiological variables enables scientists to go into more detail with their analysis and allows a better correlation of response profile and psychological event [4]. A central concern in studying gameplay is the correlation of patterns of measurement characteristics for a set of different measures with subjective characterizations of gameplay experience, such as the feeling of immersion.

Facial electromyography (EMG) is the direct measurement of electrical activity involved in facial muscle contractions; EMG provides information on emotional expression via facial muscle activation (even though a facial expression may not be visually observable) and can be considered as a useful external measure for hedonic valence (degree of pleasure/displeasure) [25]. Positive emotions are indexed by high activity at the *zygomaticus major* (ZM, cheek muscle) and *orbicularis oculi* (OO, periocular muscle) regions. Negative emotions are associated with high activity at the *corrugator supercilii* (CS, brow muscle) regions.

Facial EMG is therefore suitable for mapping emotions to the valence dimension in the two-dimensional space described in Lang's [25] dimensional theory of emotion. The *valence* dimension reflects the degree of pleasantness of an affective experience. The other dimension, *arousal*, depicts the activation level linked to an emotionally affective experience, ranging from calmness to extreme excitement. In this dimensional theory of emotion, emotional categories found in everyday language (for example, happiness, joy, depression, anger) are interpreted as correlating with different ratios of valence and arousal, hence being mappable within a two-dimensional space defined by orthogonal axes representing degrees of valence and arousal, respectively. For example, depression may be represented by low valence and low arousal, while joy may be represented by high valence and high arousal.

Arousal is commonly measured using galvanic skin response (GSR), also known as skin conductance ([24], [29]. The conductance of the skin is directly related to the production of sweat in the *eccrine* sweat glands, which is entirely controlled by the human sympathetic nervous system. Increased sweat gland activity is directly related to electrical skin conductance. Hence, GSR and EMG together provide sufficient data to provide an interpretation of the emotional state of a player in real time during gameplay.

Eye gaze tracking provides another technique, based upon the measurement of the direction of gaze as an indicator of the focus of visual attention. Among a variety of eyetracking techniques (reviewed by [11],[12]), video-based eyetracking, using combined pupil and corneal reflection, is currently the most commonly used method due to considerations of ecological validity and ease of use. In this method, following a calibration process, the eyetracking system uses a camera to track variations in reflections of diode array patterns in the eye of a subject, and these variations are algorithmically decoded to calculate where upon a computer screen a person is looking at the moment when a gaze data sample is taken.

Examples of experiments in the use of these techniques for the investigation of gameplay are described in the next section.

V. EXPERIMENTS AND RESULTS

A. *Measuring Emotions During Gameplay*

[32] describe a study investigating correlations between subjectively reported gameplay experience and objectively measured player responses within gameplay as measured by these psychophysiological measures, in order to provide cross-validated descriptions of the emotional experience of players during gameplay. The overall goal is to establish and validate a method that can precisely assess emotional modulations during gameplay in real-time. The experiment reported in this section was conducted in February 2008 in the Game and Media Arts Laboratory at Blekinge Institute of Technology (BTH) in Sweden. Although this paper is limited to the description of EMG, GSR and questionnaire data, future analyses will take into account the other data collected.

A central aim in our research is to better understand constructs of immersion and flow in the description of gameplay experience. [2] propose three gradual and successive levels of player immersion: engagement, engrossment, and total immersion. [14] subdivide immersion into three distinct forms: sensory, challenge-based and imaginative immersion. "Sensory immersion" relates to the audiovisual experience of games. "Imaginative immersion" describes absorption in the narrative of a game or identification with a character. "Challenge-based immersion" refers to a play state concentrated upon overcoming the challenges of the game. Challenge-based immersion seems to be closely related to concepts of *flow*. The flow model was introduced by Csikszentmihalyi ([9],[10]) based upon his studies of the intrinsically motivated behavior of artists, chess players, musicians and sports players, who experience high enjoyment and fulfillment in activity in itself (rather than goals of future achievement). Csikszentmihalyi describes flow as the "holistic sensation that people feel when they act with total involvement". Csikszentmihalyi specified flow as having several characteristics: balance of challenge and skills, clear goals, explicit feedback, indistinct sense of time, loss of self-consciousness, feeling of enjoyment and control in an *autotelic* (i.e. self-sufficient) activity.

The original flow model was revised by [13] into a four-channel model, which is used most commonly for describing games and gameplay experience. Defining the balance of skills and challenges is often fuzzy, which led [6] to propose different "flow zones" for hardcore and novice players and an optimal intersection, within which the experience converges towards an optimal match of challenges and abilities. However, [34] report 16 flow studies between 1977 and 1996, which all use different concepts and definitions of flow. The only commonly used questionnaire, the flow state scale [20], was designed for sports research and assessed by [21] as being usable for game research. More recently the EUfunded FUGA ("Fun of Gaming") project developed a gameplay flow scale as part of a Game Experience Questionnaire (GEQ) [19].

The study reported here, using the game *Half-Life 2* (Valve Corporation, 2004), shows a fluid transition between experiential concepts of immersion and flow. Three Half-Life 2 game levels were designed to assess the three conditions of boredom, immersion and flow. Design criteria for a *boring* gameplay experience include linearity of the game level, weak opponents of limited types, repetitive textures and models, damped sounds, no conclusive winning condition, limited choice of weapons, large number of health and ammunition packs throughout the level, and no surprises. Design criteria facilitating *immersion* include: a complex environment requiring exploration, varied opponents of increasing difficulty, rich and appropriate sensory effects, varied models, textures and lighting, and new weapons, health and ammunication being placed after significant challenges. The design criteria for *flow* are more concerned with the sequence, pace and difficulty of challenges than with environmental settings. Design criteria facilitating flow include: concentrating on the mechanics of one specific weapon and designing challenges around that, start with easy opponents and then gradually increase their difficulty and frequency through the level.

Physiological responses were measured as indicators of valence and arousal [25] together with the GEQ questionnaire assessing self-reported game experience and the MEQ Spatial Presence Questionnaire [45], thus forming the dependent variables in this experiment. As shown in a previous assessment by [31], the GEQ components can assess experiential constructs of immersion, tension, competence, flow, negative affect, positive affect and challenge with good reliability. Psychophysiological apparatus used in the experiment include facial electromyography (EMG) measuring OO, CS and ZM (described above) and galvanic skin response (GSR). GSR measurements were made using electrodes attached to the thenar and hypothenar eminences of a participant's left hand. Physiological responses were measured continuously during each play session for each experimental participant (as objective or external measures), while questionnaire data (assessing subjective individual responses) was collected for each participant in each modality. Data were recorded from 25 healthy male higher education students, aged between 19 and 38. Students were recruited within several game courses at BTH, Karlshamn Campus, Sweden. Therefore, we could assume an avid interest in games with a large proportion of participants being hardcore gamers.

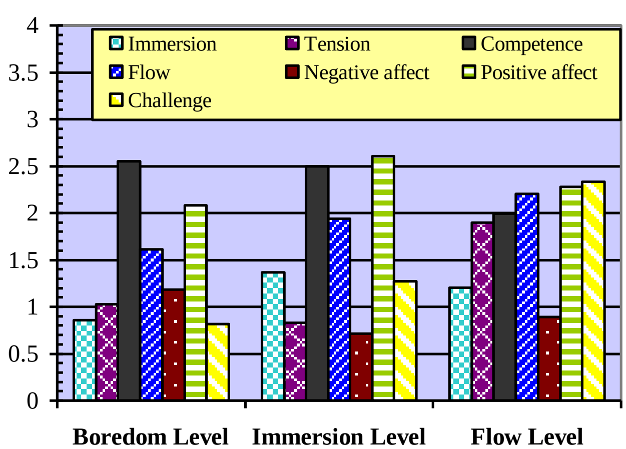

Figure 1. Mean scores for GEQ components in each level.

The comparison of mean GEQ scores from the experiment is shown in

Figure 1 (mean scores and reliability of these results have been briefly discussed in [31]). The notable results here are an increase in positive affect and immersion for the immersion level. Accordingly, this level scores lowest for negative affect items. The boredom level scores lowest on challenge, immersion and flow, but highest on competence. The flow level scores lowest on competence, but highest on flow, challenge and tension. Statistically significant variations across the level designs were not observed for immersion, competence, flow, positive affect and negative affect. Challenge and tension both showed statistically significant differences across the levels. Overall, the GEQ results seem to validate the intended level design for the flow level. However, there seems not to be enough evidence in the data to show that experiences in the immersion and the boredom levels can be subjectively discriminated.

Scores for the MEC Spatial Presence Questionnaire appear to be more significant. Spatial presence scores are lowest in the boredom level, while the level designed for immersion scores high on "self-location" and highest on "possible actions". Thus, it is very likely that what we subjectively designed for was what [14] would call imaginative immersion and that this feeling is related to spatial presence, especially in the dependency of presence upon what [45] describe as "possible actions". In contrast to this, the feeling of "self-location" might be more linked to flow in combat experiences as the flow level scores higher than the immersion level on this item. Clearly, these results present once again the need to find a more distinct terminology for the different forms of immersion.

Table 1. Means and standard deviations for EMG and GSR

Modality	EMG OO (μV)	EMG CS (μV)	EMG ZM (μV)	GSR (log[μS])
Boredom Level	7.61 (2.45)	7.56 (1.85)	8.70 (3.26)	0.90 (0.24)
Immersion Level	7.19 (1.77)	7.65 (1.78)	7.87 (2.07)	0.89 (0.28)
Flow Level	8.47 (2.70)	7.34 (2.09)	10.98 (4.89)	0.93 (0.25)

Table 1 displays the cumulative averages of psychophysiological measures over the playing time for all participants in all levels. Positively valenced emotions are characterised by increased ZM and OO activity [38]. The game level designed for the flow condition shows the highest values for positive valence (via OO and ZM activity) as well as for arousal (measured by GSR). In contrast to this, the immersion level scores lowest on valence as well as arousal. The boredom level scores similarly, but a bit higher than the values for the immersion level for all measures except CS activity. Variations in CS (negative valence) responses across levels were statistically insignificant. However, statistical significance was achieved for OO (positive valence), ZM (positive valence) and GSR (arousal). This shows that except for CS, objective physiological responses for all measures taken from an accumulated game session were significantly influenced by the different level designs.

Due to the significance of the results, an analysis of within-subject contrasts was conducted and showed significant differences of OO activity (valence) for the boredom level compared with the flow level. ZM activity (valence) was significantly different for both the boredom level vs. flow level, and the flow level vs. immersion level. In addition, GSR (arousal) showed a significant contrast for boredom level vs. flow level. [32] present details of the statistical analyses conducted in deriving these results.

The flow level scores highest for high-arousal positive emotions. This is a noteworthy finding since it links gradually increasing challenges in a competitive environment to positive emotions. Joy in this case does not come from victory or success, but averaged over a play session, it derives from challenging gameplay. The psychophysiological findings contradict the finding of [21] that EMG activity over ZM and OO (positive valence) does not have a relationship with flow . If we assume that we can accurately assess flow with the GEQ [31], then it is found in our study to be related to positive emotion as indexed by physiological responses. This study was focused on male hardcore gamers only and thus it might be that these results are only valid for this target group. In considering the limitations of the experiment design described here, it may be proposed that future research might explore different time resolutions, since emotional responses to a complete play session might be linked to smaller scale details of the modulation of emotional reactions over a sequence of specific game events of the kind studied by [33] ,[36], [37] ,[38], [39].

B. Visual Cognition and Gameplay

3D FPS (first-person shooter) game environments are virtual worlds in which the player moves their player character (PC) through the game world and overcomes barriers in the form of enemies by engaging and defeating them in combat, all seen from the perspective of the PC. Primary player tasks are survival, movement and navigation through the world, and executing tactical combat operations, typically in the form of shooting at enemies until they are dead. Visual perception provides information about the nature and location of challenges/threats, providing input to cognitive decision processes addressing where and how to move, and how and when to trigger attack commands, triggered by the player using a mouse or command key and implemented by the simulation engine of the game as the activation of a directed weapon discharge. Visual behavior is also directed by task schemas in relation to the sensory world, so visual behavior provides direct evidence for aspects of the cognitive processes directing it. [42] investigated several hypotheses addressing detailed aspects of visual processing in gameplay task performance, as a foundation for developing schema models for FPS gameplay.

The weapon representation in an FPS game is the first person view of the virtual gun that the player avatar holds. The actual aiming point for the player firing a weapon in the virtual world is typically represented by a cross-hair graphic in the centre of the screen. Gibson ([15],[16]) used the term *affordances* to refer to action potentials within an environment. In an FPS game, a representation of the aiming point of a virtual weapon, such as a gunsight, affords aiming the virtual weapon. In the case of a gun graphic with a separate active aiming point (e.g. a central crosshair in the screen), the gun graphic actually has no affordance value for aiming. The graphic is usually *visually active*, in that it moves to represent the walking or running motion of an avatar, and typically has animations indicating firing states and reloading actions. It also provides a direct representation of which weapon is currently selected and active for the player. These indicators present informational inputs to decision processes, indicating the satisfaction or not of preconditions for actions, but they do not directly target the objects of combat actions contributing to achieving in-game goals.

If the gun graphic provides a cue leading visual attention away from potential targets or the aiming cross during targeting during combat, then its design may be a distraction from optimal task performance. The hypothesis that this kind of distraction may occur derives from an earlier study [41] in which eye gaze tracking was used to investigate gameplay in a *Counterstrike* tutorial. In the earlier study, it was found that: 1. slightly more than 50% of gaze behavior fell within the left of the game display, where, *a priori*, an even distribution between left and right might be expected, and 2. approximately 50% of players visually fixate the far end of the graphical representation of the barrel of the gun, that actually has no functionality in the performance of shooting tasks, and in the region in between the end of the gun and the actual aiming cross sight. These results motivate two of the hypotheses investigated in the study reported by [42]:

H1: *the diagonal shape and position of the gun graphic cues and directs visual attention within the screen, preceding and/or independently of the attentional demands of the player's in-game task(s)* (Figure 2). This hypothesis is of interest for many serious games contexts where graphical elements designed into game environments may or may not represent functional affordances. E.g., it might distract from task performance in a way that has implications for the transfer of player performance competence to out-of-game contexts.

Figure 2. Visual attention may be cued along a line projected in the direction of the pipe of the gun.

H2: *gaze is firstly directed upon an opponent prior to shooting the opponent.* H2 relates to the degree to which the most important visual perceptual target for the performance of a task is at the centre of vision while the task is performed, as opposed to being attended to in peripheral vision.

For the study, the combat situation was also considered as a source of situation and task specific priorities in decision making. In particular, in addition to hypotheses H1 and H2, a further fundamental principle of combat is addressed by the hypothesis:

H3: *for otherwise equivalent opponents, the closest opponent will be targeted first.* Equivalence here relates to similar toughness (ease or difficulty to kill), potency (amount of harm they can inflict upon the player) and accessibility/visibility.

H3 may seem obvious, but the point of developing a scientific approach to gameplay is to provide quantitative evidence for what may otherwise be taken for granted or assumed. Data collected for

H3 and H1 may also provide an indication of the relative importance of visual cuing and (virtual) proximity if a cuing effect is found. Moreover, this study functions as a baseline, providing data for comparison with results from ongoing experiments that may be designed to investigate the distinction between apparent size and apparent virtual distance (i.e. is it the closest opponent or the one that appears the largest that is chosen first?), and then exploring the relative importance of factors such as variations in apparent toughness and potency in relation to distance and apparent size. Underlying questions here from a cognitive skill perspective include the degree to which players may be attempting to optimize combat behavior by the allocation of significance among these factors, what influences these weightings (experience, PC role preferences, adapting the level of experienced challenge?), the interplay between emotional responses and rational decision-making, etc..

The study was conducted using a Tobii Eye Tracker 1750 in which the eyetracking technology is integrated with a graphical screen upon which the stimulus is displayed. The eyetracker delivers an (x, y) coordinate representing the player's gaze position in 2D screen coordinates. The study used a double computer setup with the game application running on a separate computer from the eyetracking software but displaying the game via the eyetracker screen. The game computer executes the stimulus game, in this case using the HiFi game engine developed by the Swedish Defence Research Agency (Försvarets Forsknings Institut, FOI).

Traditionally, eye tracking studies of gaze behavior on computer screens have been limited to static 2D stimuli analysed in terms of the statistics of gaze points falling within static 2D subareas (e.g. [18]), generally referred to as *Areas Of Interest* (AOIs). In a 3D game setting we are more interested in Volumes Of Interest (VOIs), or Objects of Interest (OOIs), as objects of gaze, which move in relation to their projection onto the 2D surface of the computer screen. While OOIs can be identified by examining a plot of gaze positions superimposed over the game display (using video capture), this is extremely time-consuming. For our studies, in collaboration with FOI we developed a system in which the eyetracker is integrated with the HiFi game engine so that the engine receives gaze coordinates from the eyetracker and performs a ray trace (see [11],[12]) within the game world from each gaze coordinate to the first intercepted object within the game world. The HiFi engine then records an object log entry for the gaze point, include the time, gaze coordinates, id and location of the intercepted object. The resulting object log then includes information on all objects under the gaze point for each participant and each experimental session. Details of the integrated system, its verification process and accuracy characterization are presented in [42], [43],[44].

A typical play session within a gameplay study using this system involves the player participant playing the game in front of the eyetracker. After briefing the player with any instructions relevant to the study, a calibration process is run. Then the eyetracker screen is switched over to the game display. The operator starts game object logging and at an instruction from the operator, the player commences playing while eyetracking and game engine object logging are running. Logging stops at the end of the session and the log data is saved for analysis.

In order to test hypothesis H1 in a 3D FPS game, an experiment design is required in which it is possible to discern the effect of the position of the diagonal gun graphic in influencing the direction of visual attention during weapon firing actions. This can be achieved by varying the gun graphic between pointing toward the upper left from the lower right, and pointing toward the upper right from the lower left. These variations must occur in situations where there is a choice of who to shoot first among combat opponents on each of the left and right sides of the screen. Assuming no other biasing factors (and with handedness being tested by questionnaires during the study), if there is no visual cuing effect, then the choice between shooting the left or the right opponent first should be random and hence equally probable, leading to them having comparable frequencies of selection during gameplay. H3 can be addressed by presenting the further variable of opponent distance. Hence, if two opponents are encountered, one may be nearer than the other. Again, if distance is not a decision factor, then the near and far opponents will be equally likely to be selected, and hence have comparable selection frequencies for first attack during play.

From these considerations it is sufficient to provide a decision situation for the study where a player attack decision is made upon encountering a pair of opponents, one on the left and one on the right, in combinations of near and far distance and with either a Left or Right gun position. The dependent variable for a decision/choice point is the decision about which opponent to attack first. Each decision point can be characterized by 3 independent variables having the binary values: V1: Distance of the left opponent (Near or Far), V2: Distance of the right opponent (Near or Far), 3: position of the gun graphic (Left or Right). To make these independent variables statistically valid there should be at least 10 samples of each combination of possible values for the three variables (based upon assumptions of multiple regression [35]). 3 independent variables with binary values result in 8 possible combinations. To obtain 10 samples of each combination, a single experimental run must present a participant with 80 combat encounters, each of which is a decision situation addressing which opponent to shoot first. Too few samples may lead to a result that does not generalize (cannot be repeated), and is hence of little scientific value [35]. Hence 20 participants were involved in the experiment, resulting in data for 1600 combat encounters.

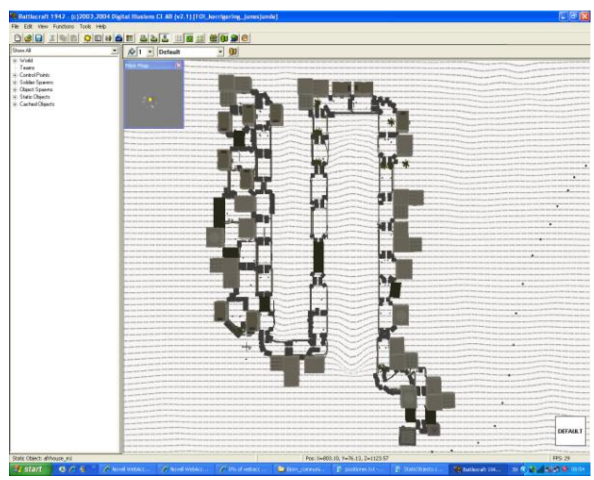

Figure 3. TopDownView of the stimulus level with 40 rooms.

The stimulus for the experiment is a computer game level implementing the combat encounters to the specification described above. Only 40 encounters needed to be implemented, since the 80 encounters experienced by the player can repeat a sequence of 40 encounters using the alternate gun position, with the starting gun position being randomized for each player. Each combat encounter was designed to take place within a single room, while the level as a whole is a series of interconnected rooms (Figure 3). Every room contains two NPC´s (non-player characters), with one each on the left and right of the room, and with their Near/Far distance positioned randomly so that players can't predict their distance beforehand. The PC (Player Character) enters each room through a narrow passage with vision blocked by a blind until within the room in order to ensure some consistency in the configuration of opponents when visually encountered. However, the distances and visual angles vary a little for each player and each room depending upon whether the PC is running or walking, orientation and also according to some freedom in position when a room is entered.

Hypothesis H1, that *the diagonal shape and position of the gun graphic cues and directs visual attention within the screen, preceding and/or independently of the attentional demands of the player's in-game task(s)*, is most clearly tested using the subset of data in which both opponents are either near or far. In this case, evidence for H1 will show preferential attention upon either the left or the right opponent, correlated with a specific gun position. It was found that data from the experiment represent the random choice case in relation to H1, providing no evidence in favour of H1 and suggesting that the gun graphic has no effect in cuing visual attention towards the left or right of screen.

There are two possible alternative attention behaviors in relation to, H2, that *gaze is firstly directed upon an opponent prior to shooting the opponent*. Firstly, the player may fire before looking at any opponent target at the centre of vision (the 'fire then look' case). Secondly, the player may direct their gaze towards one opponent while firing at the other NPC (the dual, or divided, attention case). Figure 4 summarises the frequencies of the "fire then look" case for all opponent combinations and for both gun positions. Here the combination LeftFar/RightNear for the LeftGunPosition creates the most cases of firing on an opponent before looking directly at any opponent.

	RightNear	RightFar
LeftNear	L:4.5 / R:4.5	L:4.5 / R:4
LeftFar	L:9.5 / R:7	L:3.5 / R:2

Figure 4. Summary of frequency (%) of occurrence of the "fire then look" behavior.

Figure 5 presents a summary for the divided attention case. Here the combination LeftFar/RightNear for the RightGunPosition creates the most cases of firing on one opponent while looking directly at the other.

	RightNear	RightFar
LeftNear	L:9 / R:7	L: 5/ R:3
LeftFar	L:9 / R:9.5	L:8 / R:8.5

Figure 5. Summary of frequency (%) of occurrence of divided attention behavior.

The overall conclusion is that hypothesis H2, that *gaze is firstly directed upon an opponent prior to shooting the opponent*, appears to be correct in about 88% of initial encounters. The remaining 12% represents cases where aiming at the moment of firing occurs within peripheral vision.

H3, that *for otherwise equivalent opponents, the closest opponent will be targeted first*, is most easily tested using the subset of data in which one opponent is near while the other opponent is far. In this case, evidence for H3 will show preferential attention upon the closest opponent, irrespectively of its left or right position or the gun position. Results obtained show strong evidence in favour of hypothesis H3, that in an average of 77% of cases the closest opponent will be targetted first.

These results raise the question of what factors account for the 12% of cases that do not conform to H2 and the 23% of cases that do not conform to H3. These cases may arise due to specific details of the geometry of the encounter, or due to stochastic variations in the decision processes of players.

VI. CONCLUSION

This paper began by presenting a theoretical approach to explaining observed gameplay based upon the proposed development of cognitive schema models. We then went on to consider how schema theory might relate to previously proposed explanations of the pleasures, motivations and rewards of gameplay. A variety of psychophysiological methods were presented together with accounts of how these have been used in experiments on first-person shooter gameplay: (i) to measure emotional responses of players during play, together with the use of questionnaires to establish correlations between externally measured data and self-reported subjective experience, and (ii) to test hypotheses regarding visual attention. In terms of the forms of validity that have been presented, these experiments are part of a process of establishing basic construct validity, which is a project to establish models of player and player responses, the underlying cognitive mechanisms of players, and to combine these with observation techniques allowing for the correlation of player responses with game design features. The experiments to date have established some correlations between game design features on one hand, and player emotional responses, physiological responses and visual attention patterns on the other. Further analytical work on the data gathered during these experiments will result in the definition of initial gameplay schema models. To deepen our understanding of the relative importance of the different game level design features in influencing the observed gameplay data will require ongoing experiments to examine how player responses vary systematically in relation to design variations. This will be very detailed work that represents a paradigm for ongoing game research that will take the time and energy of numerous researchers over several years to progress. In fact, this will be a never ending process, as game design and game systems continue to evolve.

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