SUBLIMINAL PERCEPTION IN 3D COMPUTER GAMES – TOWARD AN INVISIBLE TUTORIAL

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ABSTRACT

This paper investigates how perceptual and cognitive processing loads can be reduced in relation to decision-making and learning in 3D computer games. The aim is to initialize a future computer game design framework where learning and play experience can be enhanced by using subliminal cues in game tutorials.
An experiment based on cognitive psychology methods and player experience research is used to initially investigate how to subliminally affect decision-making within a 3D game environment. The experiment tests 40 participants ability for subliminal perception within a dynamic environment. The test game was applied with a subliminal priming feature presenting rapid stimuli without participants' awareness.
Results indicate that a subset of participants had stronger propensities for subliminal perception, than other participants. This group generally showed the ability of intuitive responses (had rapid response times when solving a given tasks). This group also had a higher than average experience level with playing computer games, than the group that manage the experiment less successful.
By discussing the results, it is argued that subliminal perception in 3D games is dependent on the balance between game complexity and relevance to the player. If the game aspects matches player skill level and preferences the attention allocation toward a given in-game task/goal is strengthened. A subliminal effect is more likely to occur if attention is allocated timely in task solving context, where the participant is motivated and focused by having a cognitive goal activated. Reducing irrelevant cognitive noise by focusing the different design aspects of the test game is proposed to strengthen attention allocation. This depends on the approach to guide attention. To advance in this research this paper suggests that future experiments focus on prescreened groups, with equal skill level and game preferences. Future research should focus on design aspects which support efficient attention allocation and thereby task solving.

INTRODUCTION

Imagine if a computer game tutorial could provide support without player awareness. What if the player would be able to learn the basic control elements and mechanics without having to read and remember an overload of instructions? [1,2]. Recent Human-Computer Interaction (HCI) studies propose that use of subliminal software support can reduce the perceptual and cognitive processing loads in relation to problem solving when learning software applications [3]. On that basis, this paper suggests adapting the idea of using subliminal stimuli support to establish a subliminal support framework applicable for designing 3D computer games. So far no-one has investigated the potentials of creating a subliminal game design framework.
The concept of the framework is to influence player behavior in a tutorial/learning context. By subliminal cues the cognitive perceptual load is proposed to be reduced through

subliminal perception. A more efficient learning in initial game playing can thereby be enhanced.
Proposing the complete framework is far too complex a task for this paper to resolve. But in order to initialize the framework, this paper investigates relevant aspects and methodology related to how player behavior can be affected within a 3D computer game. This is done with the purpose to founding the general basics for applying subliminal priming in a way that is applicable for the dynamic nature of 3D games.
This paper proposes an experimental methodology for merging the complex and timely nature of subliminal priming with dynamic and unpredictable 3D computer games. Execution of a cognitive experiment generally implies that every aspect is strictly controlled and timed by the experimenter. The same type of planning and prediction of participant attention is problematic in an experiment, featuring a 3D computer game setting. The player is generally in control of all behavior related interacting with the game (e.g. navigation etc.). The player attention is guided by designed game aspects; as game mechanics and graphics etc. In an experimental context it is problematic if decision making and attention is individual controlled by the player. Because in a validating experiment it is required that attention and relevant goal activation is timely to a presented prime, in order to measure if subliminal perception is occurring.
The experimental approach is based on theories and experiences adapted from the subliminal priming tradition related to *Cognitive and Social Psychology*.
The methodological framework claimed here revolves around studies on cognitive and perceptual processes, and general theories regarding human conscious and unconscious processes [4, 6]. The subliminal priming methods used in HCI experiments apply a method which requires and relies on ability to take advantage of access to a low cognitive processing load [3, 8, 9, 10, 11]. The most efficient priming concept identified is the concept of a *semantic priming effect*, which implies an associative process occurring between a supraliminal target and a subliminal prime [10]. If the target is related to a goal activating task, a timely presented prime would be able to affect decision-making [3, 7].
The environmental game structure and puzzle set-up are designed based on *Computer Game Research* studies on player involvement, with special focus on allocation of player attention allocated to involvement with strategy and decision making in relation to tasks/puzzles. The key to facilitate subliminal perception is to distribute player attention timely toward a puzzle/task. When player approaches a prime effected puzzle it should be reassured that attention is established, and a cognitive goal guiding processing toward a puzzle solution is activated.
By using this methodology, results indicates that a group of participants is generally more able for subliminal perception than others. This paper suggests that the ability of subliminal perception is related to the ability to act focused and intuitively when solving an in-game task. My findings are based on analyses of data on participant's number of attempts used to solve a given task, the time used and their general experience with playing games. I argue that these measurements are an expression of ability to allocate attention efficiently. This argument implies the assumption that the attention allocation depend on the nature of puzzles/tasks, the environmental structure, control scheme and individual game preferences.

METHODOLOGY

I will now explain the methodology more detailed in order to found an understanding of how subliminal priming is established in the test game application. Within the relevant research areas subliminal perception can be defined as perception of stimuli presented below a subjective awareness threshold [5, 6]. It is important to settle this definition in order to avoid general confusion with other terms related to the general term of unconscious processes. Previous HCI studies on subliminal support, present results based

on methods where *semantic priming effect* is obtained by presentation of subliminal stimuli [8, 10, 11,]. *Semantic priming effect* is the result of an associative process between presented priming material and subsequently presented target material. The semantic effect of a subliminal prime can be measured as an effect on participant behavior, triggered by the target. To identify the most applicable computer game context for semantic priming, the player *involvement model* was used to evaluate six different types of involvement dimensions [14]: *Kinesthetic involvement* (game control scheme), *Spatial involvement* (navigation and mapping of 3D game space), *Shared involvement* (social interaction), *Narrative involvement* (narrative/story), *Affective involvement* (emotional engagement), *Ludic involvement* (decision making and goal pursuit).
Ludic involvement was found most applicable for initial investigation of subliminal priming in computer games. Because, aspect as decision making and goal pursuit create a framework for highly predictable scenarios where subliminal support can be woven into. It is assessed that ludic aspects is relevant i this initial state because of the ability to actualize goal motivation and reassured proper attention toward the relevant game aspects.
A ludic based design can facilitate a semantic prime-target relation, implemented as an in-game puzzle. One of the multiple choices for the puzzle is functioning as target object, which is either similar or associatively related to subliminal primed stimuli (e.g. If the prime is the word car, the target could either be a picture of a car or the word car).
If this scenario can be established efficiently the player should have no other choice than approaching and solving the given puzzle, in order to proceed playing. Thereby attention is righteously allocated and cognitive goal activation is established. A relevant subliminal stimulus can be presented, and the right solution/target will trigger to affect decision-making through subliminal perception of the prime. In such scenario we infer where the player is, what he/she is approaching and why.
Shared, Narrative and *Affective involvement* was found irrelevant regarding decision making and learning purposes, they revolve around aspects as emotions; storytelling and social context which is argued to be more efficiently handled by normal conscious processes, there are not any relevant benefits using a low cognitive processing load. (E.g. it is assumed that emotions and narration have greater effect if player is aware of them.)
Spatial involvement could be relevant for focusing on learning/mapping an environment, but focusing player goal and actual attention was found to problematic at this state of the research.
Having a *kinesthetic* aspect, as learning the controls as main ratio measurement also contain relevance, but would require a prescreening, to ensure that participants are equally familiar with the required control scheme. The kinesthetic involvement was therefore dismissed, for this initial experiment.

This approach requires that each game aspect is designed to directly or indirectly support attention toward the goal pursuit. 5 main design requirements were stated for merging the theoretical concepts from *cognitive studies* and *player experience research*.

1. *Obvious assessment to task related elements:* It should be clear and timely where the player should direct attention when approaching a puzzle. This will support a clear goal activation reducing irrelevant cognitive processing. Further, it will help predicting an assumed visual focus on the screen.
2. *Set a denominating skill level for controls:* All participants should have a minimum of training in basic game controls. Reduces the difference in the cognitive load used on controlling and will release attention allocation toward task solving and goal pursuit
3. *No in-game narrative elements:* Would reduce unintended attention allocation.
4. *Simple spatial structures in the 3D game world:* Reduce the cognitive load used on navigation and mapping the environment. Basically means that a linear structured

space would be preferred in order to reduce the cognitive load in processing the environment.

5. *Careful use of rhetorical strategies:* No suddenly audio or visual effect that can trigger player´s reflexive attention and thereby interrupt executive attention allocation.

TEST GAME DESIGN

The test game was built with Source SDK development tool (Half-Life 2 engine/FPS puzzle game) and consisted of 9 puzzle-like challenges, with different complexity levels (variation in the number of targets to interact with when primed with a single prime stimuli, E.g. a three digit number vs. three separate selections of each digit). Before starting the test, the participant is given general game objective; to open doors by solving puzzles in order to find and rescue a girl. The participant is informed that cues, that could help solve the puzzles is available, hidden in the wall/floor textures in preliminary "cue" rooms, before approaching the actual puzzle. Before going into a cue room the participants is briefed with on screen text about what material the cue is presented with (e.g. a letter, a symbol, color etc.). This information is given in order to prepare the cognitive process toward being able to activate cognitive goal by guiding the mind´s conscious process looking for the cue and the unconscious mind process to be prepped for subliminal perception. After 30 sec. searching for the "cue", the participant gets access to the puzzle room where 5 or more options are presented. He/she chooses between them by aiming and shooting. Only in 3 out of the 9 challenges is there placed an actual cue that can be detected. The cues here are placed so they are easy to find. These challenges (challenge 1, 5, 7) are false and only serve deception and motivation purposes. This way the participant gets motivated on finding the cues in all challenges and keeps the illusion of cues that can help winning the game.

The subliminal prime is presented by a custom made animated texture, which presents stimuli at 4 alternating positions inside an estimated fovea visual field around an in-game aiming indicator at the center of the screen (see figure 1). The prime presentation is attached to the first person perspective camera view. So no matter how the participant navigates, the primes are presented right in front of him/her at fixed positions.

Figure 1 – Puzzle room example *(player perspective) with letter targets in a circular formation, in order to reduce a possible biased selection. The aiming indicator is in the middle of the screen and is attached to the screen so it follows any player movement.*

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EXPERIMENT

26 male and 14 female participants in the age of 21 – 41 played the test in a quiet location with a consistent light level. An individual calibration was done in relation to reduce possible awareness of prime stimuli and make the presentation as strong as possible for each individual.
The computer used in the experiment has optimal properties suitable for 3D gaming. With a Intel(R) Xeon(R) 1CPU, W3680 @ 3.33GHz 3.33 GHz processor, 12,0 GB (RAM) , 64-bit Operating system, NVIDIA Quadro 4000 with driver version 296.70. The monitor is a Samsung Sync Master S23A700D, 23" with a native 1920 x 1080 resolution at 120 Hz refreshment rate. 120 Hz provided. The monitor was set to update frames with an interval between 8.3 msec. with many system processes related to the test game the actual screen update is estimated between 8,3 – 17 msec. (no external measure was conducted).

RESULTS

The ratio measurement for determining an effect is the number of attempts used on solving each puzzle. Probability and a calculated expectation of attempts suites as the control condition for determining whether the result of attempts used could be defined as a successful (See table 1).

Table 1 – average results for all 40 participants (G40) in relation to pre-calculated expectations (E[X]). Result for challenge 2, 3, 4, 6, 8, 9 (CH2 – CH9) are very similar to pre- calculated expectation.

CH	CH 2	CH 3	CH 4	CH 6	CH 8	CH 9
E[X]	3	3	3	3	A: 18 B: 10 C: 11,5	9
Average attempts	3	3.08	2.93	3.28	10.2	8.71

CH 8 is a spelling challenges where there is 3 expectations calculated based on A: totally random choice, B: semantic rules for the Danish language C: A mix between random choice and semantic expectations.

Table 1 generally states the results as similar or very close to what was expected. Thereby no general statistical significance proves an effect.
But two relatively large groups of participants showed different levels of more distinctly propensities of being affected by subliminal stimuli. These apply to challenges with probabilities on 1/5, with a general expectation on 3 attempts. (CH 2, 3, 4, 6). Three participants (G3) or 7.5% solved these 4 challenges by using only 1 attempt, in 3 challenges and 2 attempts in one challenge. The expectation is only that 1 out of 40 participants should get as many as 3 challenges correct in first attempt. The probability for one participant with this result is 2.6%. Additional, the "fourth" challenge in 2 attempts can qualitatively be considered as supporting an effect indication for G3.
A defined group of 9 or 22.5 % (G9), (including G3), had minimum 2 first attempts selection. The expectation is only that 6 participants would manage to get minimum 2 first attempt results. Based on the results of G3 and G9 there is indications that the two groups somehow have a better basis for subliminal perception than the rest of G40. In a discussion I will look at how these results can support identifying any benchmarking factors, which

can bring the research into the next stage of focusing at the game aspect and player traits which is most applicable for this type of priming.

DISCUSSION

This discussion will look at how G9 distinct from the rest of G40; how this can explain the G9 results. In a theoretical perspective the stated distinctive findings will be discussed in relation to how it can benefit to future research.
Comparing G9 with G40 indicates that intuitive/rapid responses and a certain experience or skill related confidence can be outlined as traits for an enhanced possibility for effective subliminal perception in a computer game (see table 2). The positive results for G9 was found well distributed, which reduce the indication that another variable have biased the results.

Table 2 - Compared to G40, G9 has lower average response times for solving the challenges and the average self-reported experience is higher (Experience level rated on a scale from 0-10). This should be seen in the perspective of significantly better test results.

	Average attempts (CH2-CH6)	**Time (sec.)**	**Experience (1-10)**
G9	1.7, 1.6, 2.1, 1.5	13.5	6.2
G40	3, 3.08, 2.93, 3.28	21.5	4.3

It can be derived that execution times and reported experience indicates an intuitive determination directed at task solving, facilitated by a balanced attention allocation. Attention is available for task solving by virtue of the advantage of a balanced game complexity in relation to player skills and preferences. For less experience players' attention would rather be allocated to learning the controls than solving puzzle relevance and subliminal perception would less likely occur.
Within the findings and the pre-established methodology we can hypothesize that aspects as; *attention, goal activation and balance between skills and challenge complexity* is important for subliminal perception in a game context.
These aspects are similar to the main aspects for obtaining a mental state of *Flow* (immersed in a feeling of focus, involvement, and enjoyment with an activity).
3 main conditions for *Flow:*

1. Involvement in an activity with a clear set of goals and progress.
2. The task at hand must have clear and immediate feedback.
3. One must have confidence that he/she is capable to do the task a hand. Challenge complexity balanced with skills [12].

This argues that the cognitive processes for subliminal perception in games and *Flow* share basic conditions. Csikszentmihalyi argue that certain *autotelic personality traits* strengthen the abilities for obtaining *Flow.* Autotelic traits comprise curiosity, persistence, low self-centeredness, and conducting activities for intrinsic reasons only [12].
On the basis of these theoretical similarities for the two cognitive concepts, this paper suggest future experiments to focus on verify if there can be found any favorable *autotelic personality traits* applying to the ability of subliminal perception. If so, it could state that

personality traits also is a factor for subliminal perception in games. Such finding could level the research to a narrow focus where the potentials for a general subliminal design framework could be specified further.
Other issues that can be discussed are technology related; as system reliability along with aspects regarding LCD contrast levels, systematical biases, and refreshment rates, priming duration, priming position and priming frequency. Furthermore, there are issues in relation to ensure a proper stimuli calibration, timely presentation of prime stimuli in relation to uncontrolled eye movements. The last issue could be accommodated by use of an eye-tracking device.
How can current findings, methodology and discovered issues point toward use of subliminal perception in relation to existing game concepts?
So far, this paper can emphasize games with a consistent grey/white color scheme. This color scheme accommodates the discovered LCD monitor contrast issues with rapid stimuli presentations [13]. Games which have a cross-dimensional involvement structure are also interesting to point out in this perspective. A special close connection between kinesthetic and ludic involvement dimensions can be hypothesized to be suitable for priming at the current state. These types of cross-dimensional involvement can be argued to sharpen ability to cognitively focusing at an active goal, if the spatial structure is distinctly linear and if ludic decision-making is framed by the environmental structure. In games as *Mirrors Edge* and *Portal 2* a large part of the ludic elements are structured in close relation to the spatial structure involving navigation and the ability to instantly map the spatial structured requirements for strategy planning and action execution. The narrow spatial structures shape the nature of the puzzle/challenge. The decision-making is directed to acting on the spatial structure, which contains the majority of the ludic elements. In Portal 2 the puzzle affords to direct the cognitive processing toward the structure of the environment. Furthermore, if the options are not equally optimal the focus/attention required is also sharpened. E.g. if players don't manage to read the environment (the puzzle) properly and execute the actions righteous, the player will fail. In Mirrors Edge he/she will fall down from the roof top.

CONCLUSION

This initial attempt towards a subliminal design framework aimed at testing the potential for subliminal perception in a dynamic 3D game environment. The result indicates that participants with fast response rate and high skill/experience level have a better ability for subliminal perception within the conducted experiment. According to that it is assessed that, when game complexity matches a set of specific player preconditions and preferences, have a promising influence on the ability to allocate attention to a relevant problem-solving task and possibility for subliminal perception is enhanced.
This paper concludes that subliminal priming in computer games is not easily done, many uncertainties is discussed and identified. Before the proposed design framework can replace current obstructive and deficient tutorials with an invisible tutorial, general technological advances are needed. Future research needs to enhance and specify the answers to the question of why the effect apply to some players who these players are and how the effect can apply on a more consistent basis.

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