Network Latency in On-Line Gaming: An Engineering or a Psychological Problem?

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Abstract: Ongoing research attempts to find engineering-based solutions to the problem of network latency in multiplayer computer games. However, few studies have been conducted to examine the end-users' experience of latency from a psychological perspective. The current study examines the roles of network latency and game complexity on the subjective experience of participants playing a specially designed computer game. Results suggest that participants prefer complex over simple games, regardless of the level of latency experienced. These findings suggest the possibility of a psychological solution to some of the negative effects of network latency. It is suggested that by manipulating Relational Complexity, it may be possible to maintain a satisfactory gaming experience in the presence of latency.

*Keywords***:** Networked Multiplayer Games, Latency, Playability

I. INTRODUCTION

Distributed Interactive Applications, (DIAs) such as shared whiteboards and multi-player computer games, may be described as virtual environments that allow real-time collaboration and co-operation between geographically dispersed users. Each individual interacts with their own local representation of the environment and the application attempts to maintain a consistent representation of that environment to all users at all times. However, in practice this is often impossible to achieve, due to the distances and information transfer speeds involved [1]. Thus, participants often see slightly different events at different times. This problem is known as inconsistency and is particularly destructive to the experience of online game playing [2], [3].

Much recent research has been conducted in an attempt to find engineering-based solutions to this problem (i.e. [4]-[6]). While such work will undoubtedly help combat the detrimental effects of network latency on consistency in DIAs, it may also prove beneficial to examine the end-users' experience of this latency from a psychological perspective. Such research may help to inform us of the sufficient limits of improvements in technology needed to combat network latency. Moreover, such research may help us to identify means by which we can ameliorate the negative affects of latency by using psychological technology in the construction of games in the first instance. The results of a psychological investigation, therefore, may improve our understanding of game playing behaviour in general and guide both engineering research and game development. In addition it may shed light on playability and gaming experiences in general – an aspect of the industry that lacks rigorous analysis.

The current research approaches online games in terms of a series of cognitive challenges or problems to be solved. From this perspective, game players earn high scores by responding appropriately to each challenge presented within the game. In more technical terms, we conceive these cognitive challenges in terms of a psychological process known as stimulus equivalence [7, 8]. Stimulus equivalence is one of the simplest examples of problem solving and may be described as the following; if any one stimulus *A* is the same as any other stimulus *B*, and *B* is the same as a further stimulus *C*, then *B* is the same as *A*, *C* is the same as *B*, *A* is the same as *C* and *C* is the same as *A*. While stimulus equivalence may appear simpler than the problem solving typically required in game playing, it has been proposed as the basis for all complex human behaviour such as language, cognition and problem solving [7] and thus provides a solid starting point for the current research program.

II. DEVELOPMENT

A. Stimulus Equivalence Training Phase

The study was divided into two stages which we will refer to as the stimulus equivalence training phase and the game phase, respectively. Each phase required the development of a standalone computer program which was programmed using *Microsoft Visual Basic 6.0* software. The stimulus equivalence phase involved the development of a program for training two five member equivalence classes among a range of stimuli (i.e., *A1-B1-C1-D1-E1* and *A2-B2-C2-D2-E2*) using a matching-to-sample procedure. The actual stimuli used were nonsense syllables and coloured shapes, but are represented here in alphanumeric form for simplicity. In this procedure, one stimulus (the sample) was presented at the top of a screen. Another two stimuli (comparisons) were presented at the bottom of the screen, and the participant was required to choose which of these two stimuli goes with the sample. Corrective feedback was given after a choice was made. For example, on one trial a sample stimulus *A1* was presented along with two comparison stimuli *B1* and *B2*. If the participant chose *B1*, the screen cleared and they were presented with the word 'correct'. If the participant chose *B2*, the screen cleared and they were presented with the word ‘wrong’. Feedback remained on-screen for one second before the next trial was presented.

Training was conducted in blocks of 20 trials, in which the participant was required to respond correctly to 19/20 trials before advancing to the next block (this criterion is standard in stimulus equivalence research [8]). Four training blocks of this kind were trained sequentially: A-B, B-C, C-D and D-E. Once training was successfully completed, participants were presented with the game phase.

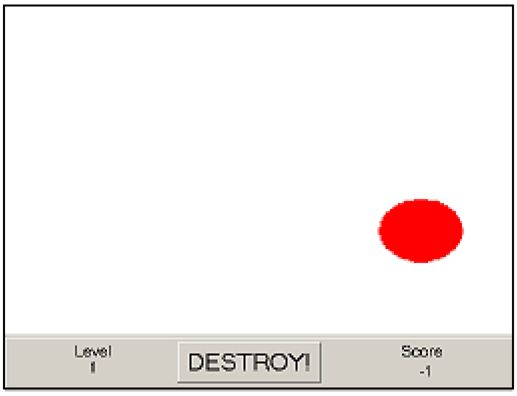

Fig. 1. Screenshot from Level 1 of the game.

B. The Game Phase

The game phase involved presenting subjects with a specially designed computer game consisting of three levels. All levels had the same user interface, as depicted in Fig. 1. Level 1 was a training level in which participants learned how to use the interface and gain high scores in the game. In Level 1, stimuli *A1* and *A2* from the stimulus equivalence training and testing phase comprised the game characters. Participants were instructed that one character could be destroyed to earn points while the other character could be saved to earned points. Characters were destroyed by clicking on an on-screen ‘destroy’ button and saved by clicking on the character itself. The participants’ score was displayed in the bottom right hand corner of the screen. Importantly, characters increased in size rapidly in order to simulate movement towards the screen. If no response was made within 2 seconds, the screen cleared and a point was deducted from the total displayed on the computer screen.

Level 2 was similar to Level 1, with the exception that no score was displayed and the characters used were the *C1* and *C2* characters from the stimulus equivalence training phase. Importantly, these stimuli had never appeared on-screen with the *A1* and *A2* stimuli before. Thus participants had to infer, in the absence of any feedback from the score indicator, which of the characters had to be saved in order to earn points and which had to be destroyed.

Level 3 was identical to Level 2, with the exception that the *E1* and *E2* characters from stimulus equivalence training and testing were presented. Again, participants had to solve the problem of which character was to be saved and which character was to be destroyed, in the absence of any feedback. Importantly, Level 3 was considered to be more difficult than Level 2. In order to respond correctly to characters in Level 2, the participants had to rapidly recall the relations between the A stimuli presented in Level 1, the B stimuli which were not presented in any game level, and the C stimuli presented in Level 2. In Level 3, participants had to rapidly recall further relations between the C, D and E stimuli in order to respond correctly to the *E1* and *E2* stimuli in the same manner as the *A1* and *A2* stimuli, respectively.

Simulated network delays were inserted on one quarter of all trials presented in Levels 2 and 3 of the game phase. These delays were designed to functionally simulate the effects of network latency. Specifically, on a delayed trial, the interface was unresponsive to users’ actions, impairing the ability of a participant to make a response within the appropriate time frame. Two separate game types were created, one in which delays lasted 0.5 seconds and one in which delays lasted 1 second. 0.5 second delays were assumed to be detrimental to game playing experience [9], while 1 second delays were assumed to have an even higher negative impact on user experience.

A questionnaire, which forms part of the Day Reconstruction Method (DRM) [10] was presented after each level of the game, as a subjective measure of both positive and negative attitudes towards that level. Importantly, the DRM has been validated with a sample of 1018, so the scale in question may represent a reliable subjective measure for the current study.

III. EXPERIMENT

Twenty two participants were recruited, all of whom were undergraduate students. Eleven of these were male, while eleven were female. Participants were promised a payment of €5 upon reaching a high score in the game. The experiment employed a 2x2 mixed between-within participants design (as depicted in Table 1). The main variables were the length of simulated delay in each game, and the level of complexity across the levels of the game. The first variable was manipulated across participant groups as participants either played the short delay or long delay games. The second variable was manipulated within groups, i.e. all participants were exposed to both levels of the game.

	Low Complexity	**High Complexity**
Short Delay	1	2
Long Delay	3	4

Table 1. A representation of the four experimental conditions employed in the study.

There were three dependent measures; participants’ score on each level of the game, and their subjectively rated level of both Positive and Negative Affect. Positive and Negative Affect are constructs statistically derived from responses to the DRM questionnaire, which was presented after each level of the game [10].

IV. RESULTS

All participants passed the stimulus equivalence training phase and advanced on to the game phase. None of the twenty-two participants failed to pass the Level 1 training level in the game phase. Mean scores were calculated for all conditions in the study (see Table 2). There was no consistent pattern of higher mean total correct responses in either game or in either level within games. However, it must be noted that the highest mean total correct responses score was for Level 3 of the Long Delay game. That is, participants achieved the highest scores in the most difficult and highly delayed game. Thus, effective playing appears not to have been affected by delay or complexity.

	Low Complexity	High Complexity
Total Correct Responses		
Short Delay	25.7	23.7
Long Delay	22.8	26.5
Positive Affect		
Short Delay	5.7	8.1
Long Delay	5.5	6.5
Negative Affect		
Short Delay	7.5	5.3
Long Delay	6.7	5.1

Table 2. Mean scores on all measures employed in the study.

As expected, Mean Positive Affect ratings were higher on both levels of the short delay game than in the corresponding levels in the long delay game, suggesting that subjects preferred the games with shorter delays. However, mean Negative Affect ratings were also found to be higher on both levels of the short delay game than in the corresponding levels in the long delay game. These results are contradictory, suggesting that further work must be undertaken to better understand the impact of different increments in delay on game enjoyment.

Mean Positive Affect ratings were higher in Level 3 than Level 2 in both the delay and non delay games, suggesting that participants preferred the more complex levels of the game. Correspondingly, Mean Negative Affect ratings were also lower in Level 3 than Level 2 in both the delay and non delay games.

A mixed between-within subject's analysis of variance was conducted to explore the impact of Relational Complexity and Level of Delay on participants' Total Correct Responses made during game play, as well as their ratings of each game type for Positive and Negative Affect. The results of this analysis are presented in Table 3. Relational Complexity had a significant effect on participants' ratings of Negative Affect. Specifically, participants found the later, more complex levels of the game significantly less negative than the earlier, less complex levels. In addition, there is a trend of higher Positive Affect ratings for Level 3 over Level 2, although this effect is not significant. Relational Complexity did not have a significant effect on Total Correct Responses. In addition, Delay Level had no significant effect on any measure employed in the experiment.

	Wilks' Lambda	F Value	P Value	Eta Squared
Total Correct Responses				
Complexity	0.999	0.023	0.882	0.001
Delay	N/A	0.00	0.99	0.00
Interaction	0.987	0.270	0.609	0.013
Positive Affect				
Complexity	0.883	1.253	0.308	0.117
Delay	N/A	0.178	0.678	0.009
Interaction	0.972	0.273	0.764	0.028
Negative Affect				
Complexity	0.674	4.598	0.024*	0.326
Delay	N/A	0.045	0.834	0.002
Interaction	0.993	0.070	0.933	0.007

Table 3. Results from mixed between-within subjects ANOVA, testing for the effects of Delay Level and Relational Complexity on the dependent variables of Total Correct Responses, Positive and Negative Affect. Those marked with an asterisk represent significant results.

V. CONCLUSIONS

A number of conclusions can be drawn from the current preliminary results. Firstly, the finding that Delay Level had no significant effect on any measure employed in the experiment suggests that increased length of delay does not significantly affect game players' enjoyment of, or performance at, a game. This finding provides a contrast to a number of other studies which have investigated the effects of network latency [1, 9]. However, this finding does not necessarily suggest that simulated network delays have no effect whatsoever on participants' enjoyment of and performance at a game. Rather, this finding may merely suggest that 1 second delays do not affect participants' enjoyment of and performance at a game any more than 0.5 second delays do. It is clearly a difficult matter to ascertain the degree to which enjoyment of a game is affected by increments in delay. More specifically, delay may reach a critical, as yet undetermined threshold, beyond which its negative impact increases negligibly or not at all. It remains for future research to identify whether this is the case and the relevant threshold that may apply.

Secondly, in the current study network latency was modeled as a fixed interval of either 0.5 seconds or 1 second. It may be argued that, given that participants could predict the length of each delay suffered, the delays could have been perceived as a particular challenge of the game, rather than a nuisance or problem with the game. In practice, network latency is rarely, if ever, predictable and typically oscillates erratically during game play. It has been suggested that this oscillation in network latency, known as jitter, is much more destructive to the game playing experience than fixed delays [9], such as those modeled in this study. Thus, future work must attempt to better understand the role of jitter on user experience in online gaming.

Thirdly, it must be noted that very different results may be obtained by using different types of games in a similar study. The game used in the current study has been contrived for experimental purposes and may lack some ecological validity when compared to modern online games. However, it must be remembered that any serious psychological investigation into game playing must employ games where all features are being simultaneously controlled or manipulated. This is difficult to do with commercial games that have not been specifically designed for this purpose.

Fourthly, Relational Complexity had a significant effect on participants' ratings of Negative Affect, where the more complex levels of the game were rated as significantly less negative than less complex levels. In addition there is a trend of higher Positive Affect ratings for the more complex levels. Thus, if future studies establish more firmly that network latency is indeed detrimental to the game playing experience, we may be able to compensate for this by manipulating complexity, thereby maintaining a satisfactory gaming experience. For example, more relationally complex games could allow for fractionally slower game play, without any loss of enjoyment from the end-user's perspective. Of course, some game players will still want to play games involving the rapid presentation of stimuli and strict time demands on responding. However, these findings provide a starting point for a psychological intervention for the problem of network latency in DIAs.

Finally, Relational Complexity did not have a significant effect on Total Correct Responses. This finding is interesting because it shows that score achieved during game play, and enjoyment of a game, are not directly correlated. High scores are not necessarily what game players find reinforcing.

It would appear that a thorough psychological study can reveal the dynamic features of an enjoyable game and provide the technology to increase those levels of enjoyment. For this reason, the current research agenda and its preliminary findings should be of interest to psychologists working in technological fields and also to engineers, games designers and marketers of on-line games. More generally, bringing rigorous psychological methods to bear on existing engineering problems may prove to be an exciting and fruitful strategy for future research.

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Conor Linehan is currently a research fellow on a Science Foundation Ireland funded project entitled 'Exploiting psycho-perceptual effects to combat latency in Distributed Interactive Applications'. In this research he is examining the psychological effects of network latency on the experience of on-line gaming. He is also examining means by which the complexity of on-line games interacts with delay as an ameliorative or exacerbating influence on the enjoyment of on-line gaming. This research is conducted within the framework of a modern behavioural theory of human language, cognition and complex behaviour, known as Relational Frame Theory.

Bryan Roche is a lecturer in psychology at the National University of Ireland, Maynooth. His primary research interest is human language and the role of language processes in the development of clinical disorders and in human development more generally. He is the author of over 60 scientific papers and has contributed to several edited books on the topics of human language, clinical and forensic psychology. He is co-author of the book *Relational Frame Theory: A Post-Skinnerian account of human language and cognition*, with Steven C. Hayes and Dermot Barnes-Holmes.

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