COMPUTER GAMES AND MULTICHANNEL AUDIO QUALITY – THE EFFECT OF DIVISION OF ATTENTION BETWEEN AUDITORY AND VISUAL MODALITIES

SŁAWOMIR K. ZIELIŃSKI1, FRANCIS RUMSEY1, SOREN BECH2, BART DE BRUYN3, AND RAFAEL KASSIER1

1 Institute of Sound Recording, University of Surrey, UK
s.zielinski@surrey.ac.uk f.rumsey@surrey.ac.uk r.kassier@surrey.ac.uk
2 Bang & Olufsen, Struer, Denmark
SBE@bang-olufsen.dk
3 Department of Psychology, University of Surrey, UK
B.De-Bruyn@surrey.ac.uk

The effect of division of attention between the evaluation of multichannel audio quality and involvement in a visual task (playing a computer game) was investigated. It was observed that involvement in a visual task may significantly change the results obtained during evaluation of audio quality for some listeners and for some experimental conditions. It was also found that this effect is listener-specific and the global effect observed after averaging the results across all listeners is small but significant.

INTRODUCTION

The rapid development of audio-visual systems in telecommunications and the entertainment industry gives rise to the question “in what way should the quality of these systems be evaluated?” According to some studies undertaken in this area, quality of audio and quality of video should not be evaluated in isolation due to the possibility of a cross-modal interaction [1][2][3] which requires complex, time consuming and thus expensive subjective tests. On the contrary, some other studies show that in some cases the effect of audio-visual interaction is very small and therefore can be neglected in the design of subjective tests [4].

The drawback of all previously quoted studies is that the division of attention between visual and auditory tasks was not controlled and therefore experimental conditions can be characterised as passive in relation to watching visual content. Therefore, these conditions were different from a domestic scenario in which listeners are involved in a story line of a movie, atmosphere of a concert, etc. Massaro and Warner undertook an experiment in which they successfully managed to control the division of attention between auditory and visual tasks, however their studies were limited only to the aspect of stimuli recognition – they have not investigated an issue of audio quality perception under selective or divided attention [5]. In this paper, we discuss the results of an experiment in which a group of subjects were asked to evaluate the audio quality of a multichannel audio system in conditions of an active involvement in a visual task. A computer game was used as a means of controlling the subject’s attention. The main research question was: “To what extent does involvement in a game change the results of evaluation of audio quality?” Before undertaking the experiment it was hypothesised that the listeners would become much more tolerant towards audio quality impairments when actively involved in a game.

The experiment described here was carried out in collaboration between University of Surrey (Institute of Sound Recording & Department of Psychology), British Broadcasting Corporation (BBC) and Bang & Olufsen within a joint EPSRC-funded project investigating subjective quality trade-offs in consumer multichannel sound and video delivery systems.

1 SELECTION OF A COMPUTER GAME

Several different computer games with surround audio were examined in order to select a suitable game for the experimental purposes. The main criteria of selection were:

- constant involvement of a subject in the game (it is required that the degree of the involvement should be the same during the whole period of time during which a subject plays a game in order to avoid any short-term situations in which a subject pays no attention to the game and is entirely concentrated on evaluation of audio),
• consistent audio characteristics,
• short period of required training,
• gender independency.

It was found that a majority of the popular computer games did not meet these criteria (e.g. action and sport games). For most of the examined games the level of the involvement in a game was highly variable and depended on the current game conditions. Moreover, a game’s audio content and its characteristics were also variable and depended on the game events and conditions. Consequently, it was difficult to use a typical action or a sport game in the experiment in which repeatability and consistency of conditions were of high importance. Moreover, the state-of-the-art games require a long period of training, which may prolong the experiment and thus make it more expensive. Additionally, some games are particularly violent which may appeal only to a limited group of subjects.

Taking into account all the discussed considerations, it was decided to use a mind/skill type of a game providing a relatively constant involvement in the task and requiring relatively little training. The game selected for the purposes of the experiment can be described as a kind of “puzzle” with moving objects. A player can rotate the objects and control direction and speed of their movement. A useful feature of this game is that it automatically increases levels of difficulty for advanced players – therefore it can be assumed the relative degree of difficulty was similar for all players regardless of their skills.

The drawback of the selected game was the fact that the native audio material accompanying the game was recorded in a two-channel stereo format and therefore was not suitable for the purposes of the experiment, since it was intended to use a game with a surround audio. Therefore it was decided to mute the native background music in the game’s software mixer and to use a high quality surround 5.1 recording instead, played back by a separate computer (SGI) equipped with software for running subjective tests (Figure 1). After the informal pilot tests, it was also decided to mute the game’s sound effects since in the authors’ opinion they were annoying in long term and also caused occasional beating effects when mixed with the external recording. The game’s voice messages were kept intact since they formed a kind of an audio feedback accompanying the visual task.

Subjects played the game within approximately 2-minute time slots. They were instructed to attain the highest possible score within this time limit.

2 SELECTION OF AUDIO MATERIAL
An instrumental jazz music recording (no vocal) was used in the experiment. The instruments (acoustic guitar, piano, bass guitar, synthesizers, drums, and percussion) were mixed down across all channels. The duration of the excerpt was 2 minutes and 10 seconds.

3 PROCESSING OF AUDIO MATERIAL
During the experimental design different types of audio degradations were considered (noise bursts, drop-outs, etc). One of the most important decisions that had to be made was whether the nature of the audio quality degradations should be static or dynamic (time-variant) or both, since it was expected that the results may depend on the temporal characteristics of audio degradations. It was decided to make this experiment as simple as possible by incorporating only static audio quality degradations, leaving more sophisticated ways of audio impairments for subsequent experiments.

![Figure 1: The arrangement of two computers and the mixing desk used in the experiment.](image-url)
low quality item obtained by low-pass filtering the original recording down to 3.5 kHz was also used in the experiment (to be explained later).

As it was described earlier, only a static type of low-pass filtering was employed in the experiment. However, it was decided to low-pass filter only the middle part of the recording, leaving its beginning and end intact (Figure 2). The reason for this was to introduce the audio distortions in the period of time during which the listeners’ involvement in the game was the highest. It was hypothesized that subjects need some time (about 30 sec.) in order to get fully involved in the game. It is also possible that a subjects’ attention may “drift” to the audio evaluation task towards the end of the game. Therefore the original recording was processed in such a way that the onsets and the offsets of the low-pass filter were overlapping with a hypothesized duration of the highest involvement of the listeners in the game – the filter was switched on about 30 seconds after the beginning of the excerpt and switched off 30 seconds before the end of the excerpt (see Figure 2). Exact onset and offset times of the filter were randomized within few seconds for each item in order to avoid the listeners learning and memorizing exact times in which the audio quality changed.

The PC computer installed in the control room with a remote keyboard and a mouse was used as a “game station”. The audio stimuli were played back with the use of the “Alex” software running on the SGI computer. The audio items were stored using 6 channel uncompressed 16-bit audio files. The audio signals were transmitted digitally from the SGI computer to the digital mixing desk (Yamaha O2R) and converted using 20-bit D/A converters operating at the 48 kHz sample rate.

**Figure 2: The way of low-pass filtering of the original recording.**

### 4 EQUIPMENT

Five loudspeakers were arranged according to the ITU-R BS.775 Recommendation [6] (Figure 3). The distance between the loudspeakers and the optimum listening position was equal to 2.1 m. The subwoofer was located behind the centre loudspeaker about 20 cm from the wall and 35 cm from the centre loudspeaker. A TV monitor (42” plasma display, 16:9 aspect ratio) was used for visual presentation of the game. The distance between the TV monitor and the listener was set to 4H, where H is the height of the viewing area (this distance conformed to [7]). The technical specifications of the loudspeakers used in the experiment and other details related to the equipment are presented in [4].

**Figure 3: Arrangement of the audio-visual equipment.**

### 5 ACOUSTICAL CONDITIONS

The listening tests were conducted in the Listening Room of the Institute of Sound Recording, University of Surrey. The acoustical parameters of this room conform to the requirements of the ITU-R Recommendation BS.1116 [8]. All channels (L, R, C, LS, RS) were aligned relative to each other with a tolerance less than ±0.3 dB SPL (measured at the reference listening position). Absolute level alignment conformed to the ITU-R BS.1116 Recommendation [8]. All measurements were performed using a 1/2” pressure microphone (Bruel & Kjaer, Type 4134) at the centre listening position (measurements were carried out only at one listening position). The microphone was positioned at a height of 1.2 m pointing upwards.

The loudness of all audio stimuli (original and processed) used in the experiment was equalised in order to minimise any experimental error due to loudness changes. Equalisation was performed...
objectively using the Moore’s loudness model [9] at the
centre listening position. The level of the audio source
material was adjusted to achieve a loudness at the
listening position of 41 sones. See [4] for more detailed
description of the applied procedure.

6 EXPERIMENTAL DESIGN
There were two types of listening sessions in the
experiment (Figure 4) corresponding to the two main
experimental conditions. The first type of sessions
involved simultaneous playing the computer game and
evaluating the audio quality. During these sessions
subjects’ attention was divided between the evaluation
of audio quality and playing the game. In the second
type of sessions listeners were asked to evaluate the
audio quality and to watch a static picture of a typical
screenshot from the game. During these types of
sessions the listeners’ attention was mainly drawn to the
evaluation of audio quality (no involvement in the
game). Originally it was planned to use a moving
picture containing a demonstration of the game,
however, during informal tests, it was found that this
drew too much attention towards the visual task, making
this condition similar to that of an active involvement in
the visual task.

![Two types of listening session](image)

Figure 4: Two types of listening sessions.

Six experienced listeners took part in the experiment.
Before the experiment each listener was given one hour
training in order to familiarise with the game. Listeners
were instructed that in sessions involving playing a
game both accurate evaluation of audio quality and
achieving the highest possible score were of the same
importance.

A single stimulus paradigm was exploited as a
subjective test method. In other words only one stimulus
was evaluated at a time. There were 12 items
consecutively evaluated within each session (Figure 5).
The duration of each item was approximately 2 min. and
10 sec. A short break after each item was scheduled for
evaluation purposes. Each listener took part in six 30-
minute sessions (three with the game and three without
the game). Both the order of sessions and the order of a
presentation of stimuli were randomised to minimise the
carry-over effect.

One of the most important issues related to the
experimental design was whether listeners should be
able to listen to the reference (original recording) only
once, e.g. before the whole experiment, or more
frequently, e.g. before each session or item. It was
decided to familiarise the listeners with the original
recording as frequently as possible in order to make the
ratings more consistent and the following approach was
applied. Firstly, the listeners could familiarise
themselves with the reference recording during the
training session. Secondly, they were instructed that
first 10 seconds of each consecutive item to be
evaluated would be unimpaired and should be treated as
having “Excellent” quality (please note that the duration
of the audio excerpts was 10 sec. longer than the
duration of the visual task to allow the subjects to
memorize the quality of the reference before performing
the visual task, e.g. playing the game – see Figure 6).
The instructions contained the information that after
first 10 seconds from the beginning of audio item the
quality may change at any time throughout its duration.
The listeners were expected to report the worst quality
noticed for the period of a whole audio excerpt. They
were asked to grade “Basic Audio Quality” defined as a
global attribute describing any and all detected
differences between the first 10 seconds of each audio
excerpt (reference) and its remaining part. The grading
scale used in this experiment is presented in Table 1.
The listeners evaluated audio quality at the optimum
listening position.

![Structure of the typical session](image)

Figure 5: Structure of the typical session

![The way of presenting the reference quality](image)

Figure 6: The way of presenting the reference quality.
Each session contained a low quality item (anchor) obtained by low-pass filtering the original recording down to 3.5 kHz. The main reason for including this item was to make the listeners more consistent in using the full range of the scale by exposing them both to the original and severely impaired recordings in each session (it was a form of “calibrating the listeners”). The scores obtained for the hidden anchor were also taken into account during analysis.

<table>
<thead>
<tr>
<th>Quality</th>
<th>Grading range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Excellent</td>
<td>80-100</td>
</tr>
<tr>
<td>Good</td>
<td>60-80</td>
</tr>
<tr>
<td>Fair</td>
<td>40-60</td>
</tr>
<tr>
<td>Poor</td>
<td>20-40</td>
</tr>
<tr>
<td>Bad</td>
<td>0-20</td>
</tr>
</tbody>
</table>

Table 1: Grading scale used in the experiment.

Because involvement in playing the game might decrease subjects’ consistency in the grading of audio quality it was decided to repeat each experimental condition six times.

7 DATA ANALYSIS

The obtained results were analysed using the following ANOVA model:

$$\text{Rating} = GM + FREQ + GAME + SUB + \text{All interactions} + \text{residuals}, \quad (1)$$

where:

- $GM$ – General mean,
- $FREQ$ – Cut-off frequency of the low-pass filter used for degradation of audio quality,
- $GAME$ – Main experimental variable having two levels (game / no game),
- $SUB$ – Subjects (listeners).

All factors used in the ANOVA model were fixed. Residuals were attributed to the inconsistency of scores between repetitions.

According to the ANOVA test (see Table A1 in Appendix), all investigated factors and interactions were significant at $p < 0.05$ level apart from the ‘GAME’ factor. This means that there was no global effect on the results of the evaluation of audio quality whilst playing the game. However, the ‘GAME’ factor was significant in interactions with other experimental factors. It simply indicates that playing a game affected the results of audio quality evaluation for some experimental conditions, for example for some cut-off frequencies.

Close examination of the ANOVA table also allows for identification of the factors or interactions that affected the obtained results the most. Differences in partial eta squared values (see last column of the table) indicate that the changes in cut-off frequency (‘FREQ’) had the biggest experimental effect ($\eta^2 = 0.94$) whereas the interaction between subjects and playing a game or watching the picture (‘GAME * SUB’) had the smallest experimental effect ($\eta^2 = 0.043$). It is important to note that there was a relatively large third order interaction between cut-off frequencies, the main experimental condition (game / no game) and subjects (‘FREQ * GAME * SUB’, $\eta^2 = 0.117$). This just shows that involvement in the game affected the way subjects evaluated audio quality for different cut-off frequencies. Therefore the obtained results should be plotted and analysed separately for different subjects.

8 RESULTS

Figure 7 shows the results obtained from the subject No. 1. The horizontal axis represents cut-off frequencies of the low-pass filter used for the degradation of the technical quality of audio signal (20 kHz corresponds to the unimpaired recording – hidden reference). For cut-off frequencies equal to 13 and 14 kHz there are significant differences between the two main experimental conditions: when the listener was playing the game the scores were “better” than during passive watching of the static picture. In other words, for these two cut-off frequencies the listener was more tolerant towards impairments of audio quality when his attention was divided between playing the game and evaluating audio quality.

Interesting results were also obtained from listener No. 4 (see Figure 8). In this case it is possible to observe a bidirectional shift of scores between the two main conditions. For the 14 kHz cut-off frequency condition there is a substantial positive “shift” of scores due to the involvement in the game, similar to that observed in the case of the listener No. 1. However, for the hidden reference (20 kHz) and slightly impaired items (16 and 15 kHz) it is possible to note a negative interaction: the involvement in the game caused a downward “shift” of scores. This is probably caused by the fact, that involvement in the game inevitably increases the error in evaluation of audio quality. Since, due to the ceiling effect (upper boundary of the scale), errors can not be made above the upper limit of the scale (100), the mean values of scores obtained for the hidden reference and slightly impaired items are (erroneously) biased downwards. In other words, all errors made for these conditions are only negative, which causes a downward “shift” of scores.
Figure 7: Scores obtained from subject No. 1. Plots based on the ANOVA model. Arrows denote statistically significant differences between conditions ($p < 0.05$).

Figure 8: Scores obtained from subject No. 4. Plots based on the ANOVA model. Arrows denote statistically significant differences between conditions ($p < 0.05$).

Figure 9: Scores obtained from subject No. 3. Plots based on the ANOVA model. Differences between conditions statistically insignificant.

Figure 10: Scores averaged across all subjects. Plots based on the ANOVA model. Arrows denote statistically significant differences between conditions ($p < 0.05$).
The results obtained for the listener No. 5 (not presented in the paper) show a similar tendency to the results obtained from the listener No. 4 (upward “shift” at 14 kHz and downward “shift” of scores for 16 kHz).

The results acquired for the remaining three listeners (Nos. 2, 3 and 6) do not display any statistically significant differences between the two main experimental conditions (see Figure 9 as an example). In other words, the remaining three listeners evaluated audio quality almost identically regardless of the type of the visual task (playing the game / watching the static picture). This demonstrates that audio-visual interactions are subject specific.

Figure 10 summarises the experimental results by presenting scores averaged across all the listeners. It is interesting to note the effects that were already discussed for the listeners Nos. 1, 4 and 5 – an upward “shift” of data for the 14 kHz and downward “shift” for the hidden reference. However, it is clear that the two plots presented in this figure are not very different. This means that the global effect on evaluation of audio quality under conditions of selective and divided attention is small but significant.

9 DISCUSSION
The nature of the audio impairments employed in this experiment can be characterised static (stationary) and therefore easier to notice during prolonged exposure. It would be interesting to find out what changes in the results could be observed if the nature of the audio degradation was dynamic, for example drop-outs, noise bursts, occasional audio compression artefacts, etc. This is a subject of the pilot study undertaken currently by one of the undergraduate students at the Institute of Sound Recording.

The results of the experiment showed that a game can be successfully used as an aid for controlling listeners’ attention. However, there are several factors that are difficult to control, and that could have biased the obtained results. For example, it is difficult to assess whether all the listeners were equally involved in the game – one can not exclude the possibility that certain listeners were less concentrated on the game than others. In order to test this effect one could possibly include in the ANOVA test all individual scores achieved during the game in the course of whole experiment. Unfortunately, these scores had not been recorded and therefore it is impossible to undertake this test (only the scores summarising the performance of each listener are available). Therefore, it is suggested that in subsequent experiments of this type both scores of evaluation of audio quality and the scores from the game should be recorded after each trial.

Another factor related to the experimental design that could have biased the results is the learning effect in the domain of audio evaluation and in the domain of playing a game. This effect is difficult to control and minimise unless a different methodology is used – for example between-subject experiments in which each subject is involved in only one experimental condition and therefore is involved in the experiment for a short period of time. In this experiment each subject took part six times in each experimental condition (six repetitions). Therefore one can not exclude the possibility that the results are biased due to the learning effect. Unfortunately, in this experiment it is not possible to study the learning effect related to the playing a game, since game scores had not been recorded after each consecutive repetition. However, the learning effect can be investigated in the domain of audio evaluation. In order to do this it was decided to perform the ANOVA test with repetition numbers included in the model as a covariate. This solution, although accounting only for linear changes in the performance level, can be a useful indication of the learning effect. According to the obtained results the repetitions (‘REPET’) are significant at the $p = 0.062$ level with the very small magnitude of the experimental effect ($\eta^2 = 0.01$) – see Table A2 in Appendix. This means that that there exists some effect of changes of scores as a function of the repetition number. Close examination of the data showed that there is a decreasing tendency in grand means of scores across repetitions (the grand mean obtained for the last repetition is a few percent smaller than the grand mean obtained at the beginning of the experiment). This can be attributed to the learning effect or to other effects like a “drift” in the use of the scale. The results presented in Table A2 show that including repetitions as a covariate slightly improved the ANOVA model (the significance levels were slightly decreased and partial eta squared values were increased in comparison with the results showed in the previously discussed Table A1).

10 CONCLUSIONS
The effect of changes in evaluation of surround audio quality under conditions of divided and selective attention was investigated. A computer game was successfully used as a means of controlling a subject’s attention. It was observed that the involvement in a game may significantly change the results obtained during evaluation of audio quality for some listeners and for some experimental conditions. It was also found that this effect is listener-specific and that the global effect observed after averaging the results across all
listeners is small but significant. Therefore it might be concluded that subjective tests investigating the audio quality of audio-visual systems can be simplified by evaluating solely audio stimuli (without visual stimuli). However, this conclusion cannot be generalised at this stage of research, since the experiment described in this paper was limited to only one type of audio degradation. Further research in this area is needed.

11 ACKNOWLEDGEMENTS
This project was carried out with the financial support of the Engineering and Physical Sciences Research Council, UK. The authors are grateful to Russell Mason (Institute of Sound Recording) for his help in selection of the computer game.

REFERENCES


APPENDIX

Tests of Between-Subjects Effects

Dependent Variable: Basic Audio Quality

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>285812.442(^a)</td>
<td>71</td>
<td>4025.527</td>
<td>88.253</td>
<td>.000</td>
<td>.946</td>
</tr>
<tr>
<td>Intercept</td>
<td>2258391.725</td>
<td>1</td>
<td>2258391.725</td>
<td>4951.557</td>
<td>.000</td>
<td>.993</td>
</tr>
<tr>
<td>FREQ</td>
<td>256037.095</td>
<td>5</td>
<td>51207.419</td>
<td>1122.639</td>
<td>.000</td>
<td>.940</td>
</tr>
<tr>
<td>GAME</td>
<td>9.780</td>
<td>1</td>
<td>9.780</td>
<td>21.4</td>
<td>.644</td>
<td>.001</td>
</tr>
<tr>
<td>SUB</td>
<td>10678.762</td>
<td>5</td>
<td>2135.752</td>
<td>46.823</td>
<td>.000</td>
<td>.394</td>
</tr>
<tr>
<td>FREQ * GAME</td>
<td>274.919</td>
<td>5</td>
<td>591.780</td>
<td>12.974</td>
<td>.000</td>
<td>.474</td>
</tr>
<tr>
<td>FREQ * SUB</td>
<td>14794.502</td>
<td>25</td>
<td>591.780</td>
<td>12.974</td>
<td>.000</td>
<td>.474</td>
</tr>
<tr>
<td>GAME * SUB</td>
<td>744.039</td>
<td>5</td>
<td>148.808</td>
<td>3.326</td>
<td>.007</td>
<td>.043</td>
</tr>
<tr>
<td>FREQ * GAME * SUB</td>
<td>2173.669</td>
<td>25</td>
<td>86.947</td>
<td>1.906</td>
<td>.006</td>
<td>.117</td>
</tr>
<tr>
<td>Error</td>
<td>16420.833</td>
<td>360</td>
<td>45.613</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2560625.000</td>
<td>432</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>302233.275</td>
<td>431</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) R Squared = .946 (Adjusted R Squared = .935)

Table A1: ANOVA table for all experimental factors.

Tests of Between-Subjects Effects

Dependent Variable: Basic Audio Quality

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>285971.376(^a)</td>
<td>72</td>
<td>3971.825</td>
<td>87.683</td>
<td>.000</td>
<td>.946</td>
</tr>
<tr>
<td>Intercept</td>
<td>449367.870</td>
<td>1</td>
<td>449367.870</td>
<td>9920.309</td>
<td>.000</td>
<td>.965</td>
</tr>
<tr>
<td>REPET</td>
<td>158.934</td>
<td>1</td>
<td>158.934</td>
<td>3.509</td>
<td>.062</td>
<td>.010</td>
</tr>
<tr>
<td>FREQ</td>
<td>256037.095</td>
<td>5</td>
<td>51207.419</td>
<td>1130.462</td>
<td>.000</td>
<td>.940</td>
</tr>
<tr>
<td>GAME</td>
<td>9.780</td>
<td>1</td>
<td>9.780</td>
<td>.216</td>
<td>.642</td>
<td>.001</td>
</tr>
<tr>
<td>SUB</td>
<td>10678.762</td>
<td>5</td>
<td>2135.752</td>
<td>47.149</td>
<td>.000</td>
<td>.396</td>
</tr>
<tr>
<td>FREQ * GAME</td>
<td>1374.595</td>
<td>5</td>
<td>274.919</td>
<td>6.069</td>
<td>.000</td>
<td>.078</td>
</tr>
<tr>
<td>FREQ * SUB</td>
<td>14794.502</td>
<td>25</td>
<td>591.780</td>
<td>13.064</td>
<td>.000</td>
<td>.476</td>
</tr>
<tr>
<td>GAME * SUB</td>
<td>744.039</td>
<td>5</td>
<td>148.808</td>
<td>3.285</td>
<td>.006</td>
<td>.044</td>
</tr>
<tr>
<td>FREQ * GAME * SUB</td>
<td>2173.669</td>
<td>25</td>
<td>86.947</td>
<td>1.919</td>
<td>.006</td>
<td>.118</td>
</tr>
<tr>
<td>Error</td>
<td>16261.900</td>
<td>359</td>
<td>45.298</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>2560625.000</td>
<td>432</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>302233.275</td>
<td>431</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\) R Squared = .946 (Adjusted R Squared = .935)

Table A2: ANOVA table with ‘Repetition’ included as a covariate.