Scale effects in 'bullet hell' games

Article · February 2015
DOI: 10.1109/GEM.2014.7048110

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***Abstract*— We experimentally evaluate display size in arcade style "bullet hell" shooter games. Two scaling methods were compared: uniform, and non-uniform. Results indicate a strongly linear increase of performance with display diagonal size. This was more pronounced with non-uniform scaling.**

Keywords*— *Scale, display size, games.

I. Introduction (*Heading 1*)

Modern displays present gamers with a wider range of game platforms than ever before. Television screens have grown ever larger, while mobile devices now come in various smaller sizes. This wide range of display sizes has increased complexity of game development. Android games, for example, are developed for up to four display sizes [1]. The closest "fit" to the device size is used. For other sizes, content is uniformly stretched by the same factor [1].

We present an experimental evaluation of scale effects in games. We propose non-uniform scaling which fixes game elements at near-native size regardless of display size. The intent is that developers could produce fewer art assets, which would be kept at fixed sized regardless of the display size. Our experiment used a "bullet hell" game that compares non-uniform scaling to traditional uniform scaling. With uniform scaling, increasing the display size proportionally increases content size. Although we get obvious qualitative results (larger is easier), we get precise quantitative results as a first step towards understanding scale effect in games..

II. Background

Scale has been studied in certain UI tasks, including navigating virtual environments [2], spatial orientation [3], pointing or point selection tasks [4, 5], steering (path following) [6] and pursuit tracking (moving target acquisition) [7]. While results generally favour larger displays, scale effects may be task dependent. Bridgeman et al. [8] found no difference due to display size in a task involving comparing quantities using graphical visualizations. Games are quite different than other UI tasks. Action games require constant attention and fast reactions.

III. Uniform and Non-Uniform Scaling

We compare two scale types, non-uniform and uniform scaling, see Fig. 1. With uniform scaling, game elements uniformly scale to match the display size, see Fig. 1b. Non-uniform scaling is shown in Fig. 1a. Note that as the play area becomes larger, game elements remain fixed in size.

IV. Experiment

Our experiment compared uniform and non-uniform scaling in a "bullet hell" (arcade shooter) game at various scale factors. Sixteen participants (mean age 22 years) took part in the study. Twelve were male. Software was developed in HTML 5 and CSS 3 using the open-source game engine CraftyJS (http://craftyjs.com/). The game engine is based on JavaScript. We ran the game in the Google Chrome web browser, in full-screen mode. Players controlled the game with a Wii U Pro Controller, and played on a 75" Samsung TV. All scale factors were simulated in software – the scale conditions are summarized in TABLE I.

TABLE I. Experiment Scale Conditions

Scale Factor	Width (pixels)	Height (pixels)	Diagonal (pixels)	Diagonal (inches)
Small	614	346	705	24 in.
Medium	945	532	1085	37 in.
Large	1280	720	1469	50 in.
Full	1920	1080	2203	75 in.

The experiment used a 2×4×5 within-subjects design. The independent variables and their levels were scale type (uniform, non-uniform), scale factor (small, medium, large, full), and trials 1 through 5. The eight combinations of scale type and scale factor were counterbalanced according to a balanced Latin square. Trial progressed sequentially and each trial was 1 minute long. Participants played 6 such trials for each condition, the first of which was treated as a practice trial.

V. Results

Results were analyzed with repeated measures ANOVA. Longest life duration was the maximum time spent alive in a condition. The main effect for scale type on longest life duration was significant ($F_{1,15} = 27.2$, $p < .001$), as was the main effect for scale factor ($F_{3,15} = 228.6$, $p < .0001$). Their interaction effect was also significant ($F_{3,15} = 31.2$, $p < .0001$).

Enemy kill ratio was the percentage of enemies destroyed by the player in each trial. See Fig. 3. The main effect for scale

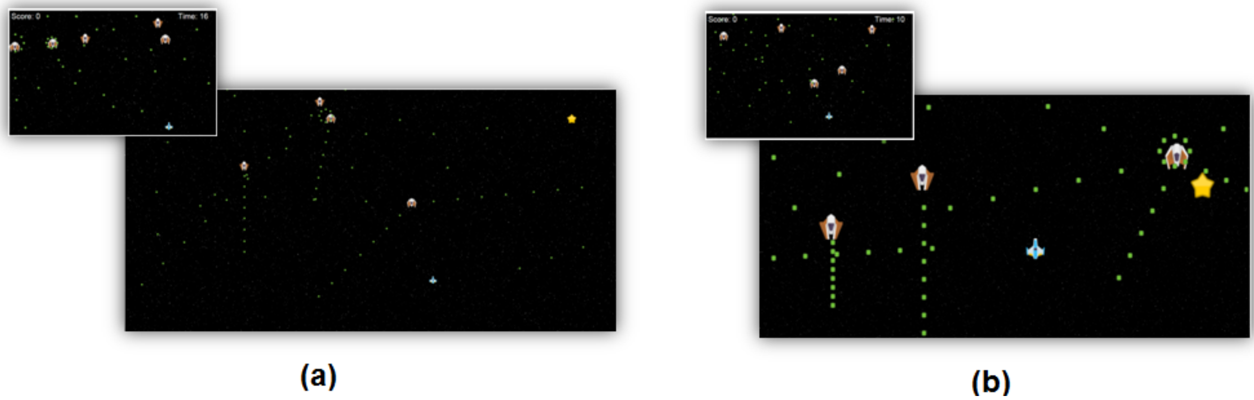

Fig. 1. The two scale types used in our study. (a) Non-uniform scaling at a large and small scale. Note that in-game elements (player and enemy ships, bullets, etc.) stay consistently sized while the game play space becomes larger. (b) Uniform scaling at large and small scale. In this condition, all in-game elements become larger with larger scales (or smaller at small scales).

factor on enemy kill ratio was significant ($F_{3,15} = 92.2$, $p < .0001$), but scale type was not ($F_{1,15} = 1.8$, $p = .22$). The interaction effect was significant ($F_{3,15} = 18.2$, $p < .0001$).

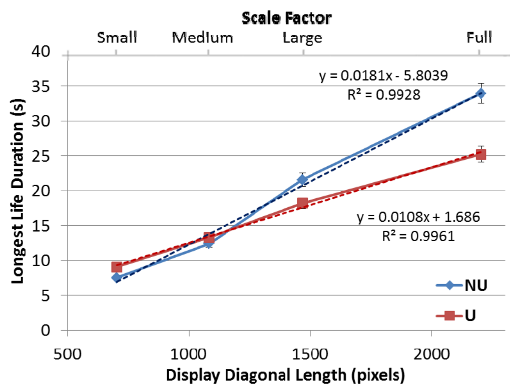

Fig. 2. Longest life duration for each condition. Error bars show ±1 *SE*. Dashed lines show linear regression model for each scale type.

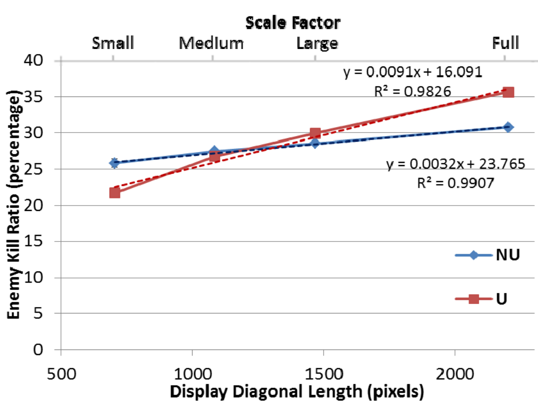

Fig. 3. Enemy kill ratio for each condition. Error bars show ±1 *SE*. Dashed lines show linear regression model for each scale type.

VI. Discussion and Conclusions

Almost universally, non-uniform scaling offered better performance at the larger scale factors. Non-uniform scaling allows better use of the available screen space, making the game easier. However, this suggests inconsistent player experience across scale factors using non-uniform scaling.

Effectively, the larger the screen size became, the more open space was available. Naturally, this decreases the game difficulty. Conversely, using smaller scales with non-uniform scaling yielded a much more difficult game. The participants also indicated that they were aware of this.

Future work will address this difference due to scale factor. In particular, we seek to normalize player performance and experience across different display sizes. The regression models presented in Figures 2 and 3 are a first attempt at better understanding the effects of scale – in future, we seek to "flatten" these lines.

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