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ORIGINAL ARTICLE

Pixel Art Style Affects Temporal Estimation in Visualized Situations

Suomiya BAO

University of Tsukuba, 1-1-1 Tennodai, Tsukuba-shi, Ibaraki 305-8577, Japan

Abstract: This study intends to discuss the potential effects of pixel art style on people's perception. In Experiment A, 166 participants were randomly assigned to 2 groups, observed the same dining situation in pixel and vector art style respectively. Results showed that art style did not have a big impact on emotions, however raised a hypothesis that people might tend to believe the situation is in a past era when observing the pixel version. To test that, in Experiment B using 6 different dining situations involving 189 participants, it is found that people in pixel group indeed tend to believe that the situations happen in an earlier period. The effects of pixel art style on imagination remains unclear. This study revealed the potential impact of pixel art style on people's temporal estimation. This phenomenon could be taken advantage of in game design and visual communication design.

Keywords: *Situation, Pixel art style, Temporal estimation*

1. INTRODUCTION

1.1 Background

Previous investigation suggested that visualized situations using simple or detailed sketches was an effective way to represent different product usage situations (e.g. dining situations). The more detailed a visualized situation is illustrated, the stronger and specific emotions can it evoke, whereas a simple version of the situation could avoid providing too much information for people to relate to themselves [1]. It is suggested that a visualized situation should be as simple as possible, with the right level of simplicity that provide just the needed information to the observers. However, no matter how simple a sketch could be drawn, it always has a certain art style. For example, the visualized dining situation in the previous study [1] was drawn by hand on paper, with a relatively realistic art style. There is no discussion made on how the art style of these sketches could make an impact on people's comprehension and emotion.

To answer this question, there are many steps to be made. First of all, the definition of "art style" is important to be clarified. An art style of an illustration could be easily associated with the specific drawing style consistently used by any mangaka (professional comic book illustrator). However, any specific art style that recognized by people is a certain combination of various aspects (e.g. lines, colors, shadows, proportions, etc.). For example, for the aspect of proportions, illustrators could create a cuter art style by simply adjusting the proportion of the human bodies and objects. Therefore, among all these basic aspects of art style, it is essential to study on each one of them separately. One of the most basic aspects is how the dots and lines are drawn. Some art style might use natural lines, while some might take advantage of different pencil strokes. However, there is a more fundamental difference between how the dots and lines are drawn.

A 2D visual illustration is basically either drawn with a vector art style or pixel art style. The simplest difference is, when the lines are continuous, cannot be visually demolished into smaller units, such as dots, it is considered as a vector art style. On the other hand, when the lines are composed by smaller, equal-sized units that are visible to human eyes, it is usually considered as a pixel art style [2]. That being said, pixel art can become vector art, if the pixels are small enough that human eyes cannot recognize them.

Pixel art could be found and traced back to the very early age of human civilization, such as mosaic art from Pompeii [3]. Our ancestors used small, equal-sized tiles to draw arts on floors and walls. Later in the history of fine arts, as an iconic art style, pixel art was also a successor to cubism and constructivism [4]. However, in modern period, it is much more popularized thanks to the boom of computer and digital graphics, and the rise of the game industry. Game designers were "forced" to create a graphics with pixel art, because of the limited resolution of display and low processing power of the computers back in the very early days of video games. Two well-known examples are two of the oldest video games, Space Invaders (1978) and Pac-Man (1980) [5, 6]. In 2000s, with the rapid development of computer graphic technology, game designers were released from the

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restriction of pixel art. Thanks to advanced technology, visual graphics in video games became more and more realistic and rich in presentation. Although astonishing graphics are easily achievable by game developers nowadays, pixel art style did not fade away. In fact, it is getting even more popular in recent years [7]. Pixel art is becoming an artistic choice for game designers [8]. In the Game Award 2018, a video game using pixel art style, called Celeste (2018, [9]), was even nominated as a candidate for the Game of the Year Award, alongside other AAA titles. What is the value in pixel art style?

It is said that there is a difference in the aesthetic values derived from pixel art [3]. As a defining art style of gaming, pixel art not only brings nostalgia, but also attracts people with its minimalist style that fill the blank of imagination [10]. Pixel art games require the players to "fill the gaps" with their imagination, to make sense of it with the little information, and this additional effort is enjoyable, like reading a book compared to watching a movie [8].

1.2 Research Questions

What makes pixel art style special? Is it just a visual style that provides a little diversity to video games and visual communication, or is it more than that? What happens to our comprehension, emotion, and perception on an illustration if we simply pixelate it?

This study intends to investigate the difference between pixel art style and the counterpart: vector art style, using visualized situations, to uncover whether there is a gap between the comprehension, emotion and perception in these 2 art styles.

2. EXPERIMENT A

2.1 Hypotheses and Objectives

Experiment A was carried out to investigate the difference between art styles in a visualized situation, in terms of comprehension and emotion. Moreover, when a visualized situation being used as a visual stimulus, it is important to be perceived as realistic and not difficult for people to picture themselves being in the situation. Therefore, how realistic the situation is and how difficult to picture oneself being in the situation are investigated.

As the most fundamental aspect of art style, pixel and vector art style were chosen as the target of this study. Based on the literature review, pixel art style could evoke a more nostalgic emotion, and trigger imaginations. Here we consider that imagination is important in how realistic a situation feels, and how easy to picture oneself being in the situation. The nostalgic emotion might be stronger for older people, since younger generations might have less experience with pixel art style in the early period of computer graphics. Therefore, age could play a role specifically for pixel art style. If a visualized situation is drawn in pixel art style, it might be easier for people to "fill the blank/gaps", perceive it as a realistic situation, and picture themselves being in the situation. In addition, such effect might be stronger for older people. Since gender's effect on emotion was discovered in previous study [1], the potential impact of gender on these could not be ignored without testing.

the objectives of Experiment A are below:

1. To explore whether any of the emotions evoked by a visualized situation would change between pixel and vector version, and between different gender.
2. To test Hypothesis 1 ($H1$): people perceive a situation as a more realistic one, and can picture themselves in the situation more easily when presented with the pixel version of the situation. Gender also affects these perceptions.
3. To test Hypothesis 2 ($H2$): in a pixel version of the situation, it is easier for older people to perceive it as a realistic one, and picture themselves being in it, whereas there won't be such effect of age in the vector version.

2.2 Method

1) Stimuli:

There is a limited number of studies that have developed a structured list of visualized situations. Given the complexity of situations, categorization methods may vary, and each category may contain vastly different cues, resulting in stimuli that are difficult to compare. Therefore, to address this challenge, it is essential to narrow down the situations by selecting a theme. In a prior study [1], a list of dining situations was developed and tested in a series of experiments, resulting in a more reliable process of generating stimuli. Building on this work, this study has selected dining situations used in the previous study as stimuli. Among the 6 typical dining situations summarized in the previous study [1], one situation was selected because of the strong responses in emotion. Afterwards, since the sketch was already drawn in the vector art style, the pixel art style version was created using Adobe Photoshop. The canvas was adjusted to make sure the general line thickness is 1 pixel but not too much thicker or thinner than the vector version. Finally, two sketches were adjusted to fit the screen in the same size (Figure 1).

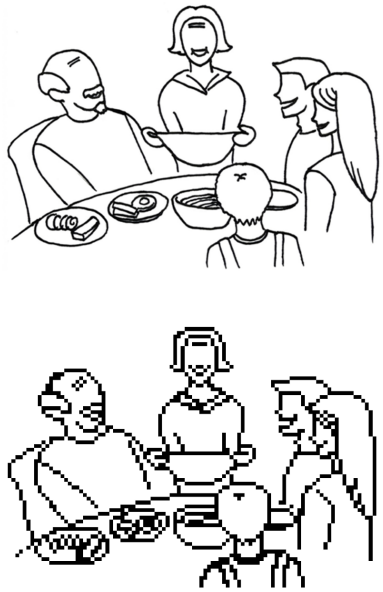

Figure 1: Vector version (top) and pixel version (bottom) of the dining situation sketch used in Experiment A

2) Questionnaire:

A questionnaire was created including questions that investigate the comprehension and emotions on a situation. According to the 5 basic cues of a situation ((i) persons, relationships and social interactions; (ii) objects; (iii) events and activities; (iv) locations; (v) time) (e.g. [11-13]), the questions for comprehensions were composed by 5 simple questions [14, 1]. Questions for emotions were based on previous study [15, 1], collecting the major 15 emotional responses of participants on dining situations using 5-point Likert scale. In addition, 2 questions (1. How realistic is this illustration? 2. To what extend are you able to picture yourself in this situation?) with 5-point Likert scale were also included in the questionnaire. The age and gender of the participants were also collected (Table 1).

Table 1: Questionnaire summary of Experiment A

Comprehension questions	Who and what relationship in the situation		
	What objects in the situation		
	What kind of event or affair		
	What period is it happening		
	Where is it happening		
Emotion items	Joy	Coldness	Quietness
	Liveliness	Refreshment	Boresome
	Happiness	Weirdness	Loneliness
	Peacefulness	Freedom	Crampedness
	Warmth	Emptiness	Togetherness
Other	How realistic is this illustration		
	To what extend are you able to picture yourself being in this situation		
	Age		
	Gender		

2.3 Experimental Procedure

The experiment used a between-subject design, participants were randomly assigned to 2 groups, one being the pixel group and the other being the vector group. Firstly, they were asked to observe the dining situation sketch. Afterwards, they were required to answer the questionnaire.

2.4 Analysis

First, responses on comprehension were used to validate participants' basic understandings of the dining situation. Afterwards, ANOVAs (Analysis of Variance) with 2×2 factorial design (IV: "Art style" and "Gender", DV: emotional responses) were conducted to determine whether there were significant effects of art style and gender in each evoked emotion. ANOVAs (IV: "Art style" and "Gender", DV: "realistic" and "picturing oneself") were also conducted to test $H1$. Finally, to explore the relationship between participant's age and how realistic / how easy to picture, independent sample t-test and correlation analysis were conducted respectively on the 2 groups (pixel art and vector art) to test $H2$.

2.5 Results

1) Demographics:

As the perception of pixels can vary depending on the size of the pixels presented on a screen, it was necessary to ensure that participants responded on screens of a similar size during the experiment. To recruit participants, we utilized SurveyMonkey's Audience service, and based on the device type detection function of the service, we found that the vast majority (>95%) were using smartphones. Consequently, we excluded responses from participants using other devices, such as desktop or laptop computers, to ensure that all participants viewed the pixel illustrations on a screen of a similar size. In addition, after discarding questionnaire responses with invalid answers (e.g., random typing in the answer box), 173 total responses remained. In addition, in the comprehension questions, almost all participants correctly understood the basic cues of the situation, answering that the dining situation was about a family, having food together at home. Expect for a few participants thought they were friends and waitress eating in a restaurant. 2 participants thought that a lady was trying to sell a purse in the situation. After excluding these outlier answers, in the end there were 166 total valid responses (69 males & 97 females) that understood the situation correctly. Analyses were done on these 166 responses. The average age of participants was 37.43 years (SD = 12.38), ranged from 20 to 60 years old. For the random assignment,

65 participants were assigned to the pixel group (average age = 37.6, SD = 12.33), including 30 males and 35 females, while 101 participants were assigned to the vector group (average age = 37.32, SD = 12.47), consisting of 39 males and 62 females.

2) ANOVAs on Emotions:

ANOVAs (IV: "Art style" and "Gender", DV: emotional responses) were conducted on all emotion items in Table 1. According to Armstrong's suggestion [16] on when to use Bonferroni correction, since the first objective of the study is an exploratory investigation with no hypothesis, and it was not imperative to avoid a Type I error, Bonferroni corrections should not be applied to these ANOVAs. Among all the results from ANOVAs, there were no significant main effects of art style on emotions. On the other hand, significant main effects of gender were found on emotion items such as "Refreshment" ($F(1,164) = 5.31, p = .022$), "Quietness" ($F(1,164) = 5.07$, $p = .026$), "Loneliness" ($F(1,164) = 5.73$, $p = .018$), and "Crampedness" ($F(1,164) = 4.49, p = .029$). Several significant interactions were also found on "Happiness" ($F(1,164) = 3.92$, $p = .049$), "Refreshment" ($F(1,164) = 6.24$, $p = .013$), "Freedom" ($F(1,164) = 4.52$, $p = .035$), and "Togetherness" ($F(1,164) = 4.44, p = .037$).

3) ANOVAs on "How Realistic" and "How Easy to Picture":

ANOVAs (IV: "Art style" and "Gender", DV: "Realistic" and "Picturing oneself") were conducted to test *H*1. No significant main effect of either art style or gender was found. No interaction between them was found, either.

4) Independent sample t-tests and Correlation Analyses on "How Realistic" and "How Easy to Picture":

Independent sample t-tests and correlation analyses were carried out to test *H*2. In conducting the t-test, the age range of the participants, spanning from 20 to 60 years old, was utilized to categorize participants into two distinct groups: older (age>=40) and younger (age<40). This was achieved by setting a threshold age of 40 years to separate relatively older and younger participants. In the pixel group, a between-subjects t-test was conducted to compare the means of older group ($M = 3.16$, $SD = 0.85$) and younger group ($M = 2.45$, $SD = 1.31$) on the variable "Picturing oneself". The results indicated a significant difference between the two groups, $t = 2.87(61)$, $p = .006$, with older group scoring higher on average than younger group. Such significant result was not found in the t-test in the vector group (Figure 2). There was also a low positive correlation between "Age" and "Picturing oneself" ($r = .30, p = .014$), indicating that older participants tended to be able to picture themselves in the situation easier than younger participants, only found in the pixel group.

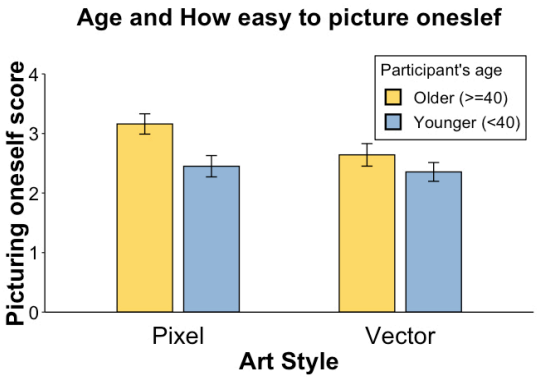

Figure 2: Bar plot showing the differences among older and younger participants in pixel and vector groups, on the evaluation of "How Easy to Picture oneself"
The error bars show standard errors.

2.6 Discussion

First of all, results supported previous study [1], showing that gender plays a big role in evoking emotions in a visualized dining situation. Compared to gender, there was no significant main effect of art style on any of the emotional responses on the dining situation. This suggests that simply by changing the art style of a visualized dining situation from vector to pixel might not provide much effect on the emotions that related to the dining situation.

When applying a visualized dining situation in various scenarios, it is considered that how realistic the situation feels and how easy to picture oneself being in it are very important. Results showed no difference among the two art styles and two genders, indicating that no matter pixel or vector, male or female, the level of "how realistic it feels" and "how easy to picture oneself being in it" might not change. Changing the art style from vector to pixel wouldn't make people feel more realistic on the situation, wouldn't make it easier for people to picture themselves being in the situation. *H*1 was not supported. Although it is being said that pixel art style could invite more imagination to "fill the gaps/blank" [8, 10], simply by pixelating the lines might not work. It could be more due to the simplicity of the visual stimuli, since the difference between pixel games and other games are usually not just the art style, but also the simplicity regarding many visual aspects.

When taking the age of participants into consideration, it is found that when observing the pixel version of the dining situation, it is easier for older people to picture themselves being in it, and such result was not found for the vector version. This partially supports *H*2, saying that the pixel art style indeed makes older people relate themselves more. However, since this effect of pixel art style was not found for "Realistic", it cannot prove that older people actually can imagine more because of their

experience with pixel art compared to younger generation. No matter how old the person is, he/she sees no difference on the level of how realistic it is between pixel and vector version of the dining situation. In general, it is assumed that if individuals can easily imagine themselves in a situation, it may appear more realistic to them. Therefore, a new question is: why can older people picture themselves more easily in the dining situation, but not necessarily feel it more realistic than younger generation when observing a pixel version of the dining situation?

To answer this question and understand this difference between the perception of older people and younger people on the pixel art style, additional analyses were conducted. To ensure the validity of the responses, screening was performed, and 'bad' answers were removed based on whether the participant demonstrated an understanding of the basic cues of the situation. Comprehension questions in Table 1 were used as a criterion for validity, with responses indicating an understanding of the relationships between individuals and objects considered valid. For example, in the first question "Who and what relationship?", responses with the answer of "family" or "relatives" were considered valid, however responses with the answer of "customers and sales associate" were eliminated. In general, all responses demonstrated mutual understanding of the situation among the 5 questions, except for the fourth question: "What period is it?". The ambiguity of this question caused participants understood the question in different ways. Among all 166 responses, 53 responses answered the questions with the period of different eras, such as either past era (it looks like in the 70s/80s, etc.) or modern era (it looks like modern time, etc.), whereas 113 responses answered the question with the different period of time of a day, such as dinner time, evening, morning, etc. Since the dining situation was not illustrated with any intention to represent a specific time (although "dinner" seems more appropriate, answers with "morning" were not considered incorrect), all these answers were considered valid and were not eliminated. However, in order to understand how people perceive pixel and vector versions of the dining situation differently, the first group of responses (53) with the answer of either past era or modern era could be considered as the temporal estimation of the situation (summarized in Table 2). As can be seen by the frequencies cross tabulated in Table 2, there is a significant relationship between art style and perceived era, $X^2(1, N = 53) = 7.67,\ p = .006$. Participants in the pixel art group were more likely to perceive it happening in a past era than were in the vector group. This might be one of the main reasons why older people were able to relate to themselves, imagine themselves being in the situation, without necessarily feeling more realistic about it. Since the pixel version of the situation actually looked "older", the older participants could associate themselves to it more, because they have been living in the past era compared to younger ones. Younger people could also think the situation is a realistic one, it is just more difficult for them to picture themselves being in the situation because it looked like something happening in the past era when they were not born yet. It could be clearly seen in Table 2 that the dining situation itself is not "old" at all, since participants in the vector art group believed that it was more likely happening in a modern era. It is just the art style of pixel made it looked "older". This brings up a hypothesis that pixel art style might affect our temporal estimation of a visualized situation.

Table 2: Art style and temporal estimation in Experiment A: numbers of participants in each group of art style, estimated different period of the situation, past era (70s, 80s, etc.) or modern era (modern time, today, etc.)

Art style	Past era	Modern era
Pixel	14	9
Vector	7	23

3. EXPERIMENT B

3.1 Hypotheses and Objectives

Based on the findings in Experiment A, there is a tendency that pixel art style might affect temporal estimation, lead to perceiving the time of the event being in an earlier period. Since this was only observed by a follow-up chi-square analysis on counting answers in the free comments, a more well-planned experiment using more visualized situations was needed to validate this hypothesis. On the other hand, it is unclear whether gender could also affect temporal estimation, therefore gender should also be considered as a factor. In addition, since the questions used in Experiment A did not discover any connection between pixel art style and imagination, Experiment B tried to explore whether pixel art style could trigger more imagination.

the objectives of Experiment B are below:

1. To test Hypothesis 3 (*H*3): when dining situations were illustrated in pixel art style, people would estimate it being in an earlier period, compared with vector art style. Gender might also affect this phenomenon.
2. To find out whether a dining situation in pixel art style would trigger more imagination.

3.2 Method

1) Stimuli:

Following the procedure of creating the dining situation sketch in Experiment A, a total number of 6 visualized situations were pixelated (Figure 3).

2) Questionnaire:

The questionnaire contains 5 questions. The first question asked about participant's temporal estimation of the dining situation. Participants could select the most likely option from 9 different decades. The second question allows participants write down free comments, list up anything that came into their mind when they were presented with the visualized situation (Table 3).

Questions 3, 4, and 5 were designed to inquire about participants' preferences regarding video games, pixel art style in video games, and pixel art style in general, in order to investigate whether there is a relationship between the level of preference for pixel art or video games and temporal estimation in the pixel group.

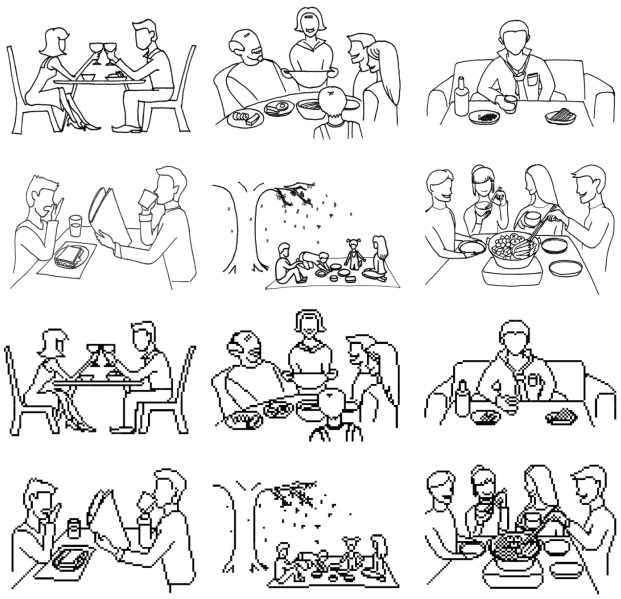

Figure 3: Vector version (first row, left to right, situation No.1−3, second row, left to right, situation No.4−6) and pixel version (first row, left to right, situation No.1−3, second row, left to right, situation No.4−6)

Table 3: Questionnaire summary of Experiment B

Questions	Answer (options)
(1) What is the most likely time period does this situation look like?	1950s, 1960s, 1970s, 1980s, 1990s, 2000s, 2010s, 2020s, 2030s
(2) Please list up the words came into your mind, or any thing (concept, emotion, event, etc.) you can imagine based on this illustration, as many as possible.	Free comments.
(3) How much do you like video games?	5-point Likert scale
(4) How much do you like pixel art style in video games?	5-point Likert scale
(5) How much do you like pixel art style in general?	5-point Likert scale

3.3 Experimental Procedure

Experiment B also used a between-subject design, participants were randomly assigned to 2 groups, one being the pixel group and the other being the vector group. In each group, participants observed each one of the 6 dining situations, and answered the first 2 questions, until completing all 6 dining situations. Questions (3), (4), (5) were asked only once at the end of the experiment.

3.4 Analysis

Participants' selection in the first question were converted into a 9-point Likert scale. The linear relationship between temporal estimation and age was confirmed, therefore age was considered as a covariate that should be controlled in the analysis. Factorial ANCOVA (Analysis of Covariance) was conducted, using art style (pixel & vector) and gender (male & female) as independent variables, age as covariate, and temporal estimation as dependent variable, to see if there is a significant difference between vector version and pixel version, male and female, on the estimated time period of the situations. The second question was analyzed using thematic analysis [17]. All participants' free comments were reviewed by the researcher. Specific themes representing different levels of imagination would be summarized. Afterwards, the difference between pixel group and vector group in the levels of imagination would be discussed using basic statistics of the themes.

3.5 Results

1) Demographics:

After excluding answers using desktop or laptop devices, and discarding invalid and incomplete questionnaire responses, valid responses (n = 189) were used in the analysis. Pixel group (n = 94, 50 females) has an average age of 46.03 (SD = 17.40), and vector group (n = 95, 52 females) has an average age of 43.67 (SD = 17.97). An independent samples t-test was conducted to compare the mean age of the two groups, and the test statistic was $t(198) = .94$, $p = .35$, showing that there was no significant difference between the age of the participants in pixel group and vector group.

2) Temporal estimation:

First of all, the scatter plot in Figure 4 shows an example of the linear relationship between age and temporal

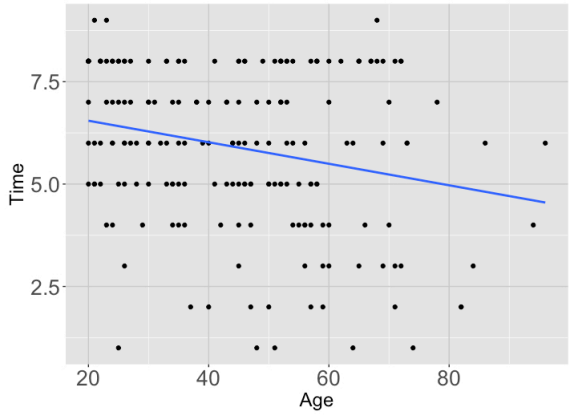

Figure 4: Linear relationship between "Age" and "Time" (temporal estimation) in situation No.1 in Experiment B

Table 4: Mean scores of temporal estimations for each condition

Situation No.		Pixel Male	Pixel Female	Vector Male	Vector Female
1	M	6.41	5.42	5.93	5.85
	SD	1.62	2.23	1.82	2.01
2	M	5.70	3.90	5.77	5.10
	SD	2.12	2.37	2.01	2.35
3	M	6.14	6.06	6.81	6.58
	SD	1.89	1.98	1.61	1.79
4	M	5.27	5.22	6.30	6.44
	SD	2.07	2.01	1.74	1.51
5	M	4.98	4.74	5.44	5.44
	SD	1.89	2.11	1.87	2.06
6	M	5.34	5.94	6.91	6.19
	SD	2.03	1.72	1.25	1.72

The scores were converted from 9-point Likert scale, with 1 being 1950s, and 9 being 2030s. The higher the score is, the later the period is estimated by the participants.

estimation in situation No.1. Similarly, linear relationship was found in other situations, too. As a continuous variable, age could vary along with temporal estimation, which was controlled as a covariate. A two-way ANCOVA was performed to examine the effects of art style and gender on temporal estimation, after controlling for age.

Table 4 shows the means and standard deviation of the scores of temporal estimation for each condition in all situations. The scores were converted from 9-point Likert scale, with 1 being 1950s, and 9 being 2030s. Therefore, a mean score of 6 means that the participants in that group estimated the situation happening around 2000s. The higher the score is, the later the period is estimated by the participants. The lowest score is observed in female participants in the pixel group. When they were rating situation No.2, the average score was 3.90 (later in the 1970s). The highest score is in male participants in the vector group, showing a mean score of 6.91 (later in the 2000s).

Table 5: Results of ANCOVA on temporal estimation

Situation No.	Art style		Gender		Art style : Gender	
	F	p	F	p	F	p
1	.05	.83	3.37	.07	1.51	.22
2	3.57	.06	14.30	<.01 **	2.02	.16
3	4.31	.04 *	.29	.59	.33	.56
4	17.64	<.01 **	.03	.87	.12	.73
5	3.40	.07	.11	.74	<.01	.99
6	11.14	<.01 **	.04	.85	8.55	<.01 **

Table 5 shows the result of ANCOVA analysis. There was no significant effects or interaction in situation No.1 and No.5. In situation No.2, there was a significant main effect of gender on temporal estimation, $F(1, 184) = 14.30$, $p < .001$. Pairwise comparison showed that females significantly estimated the time period earlier than male ($\Delta = 3.71$, $p < .001$). In situation No.3, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 4.31$, $p = .039$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 2.08$, $p = .039$). In situation No.4, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 17.64$, $p < .001$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 4.22$, $p < .001$). In situation No.6, there was a significant main effect of art style on temporal estimation, $F(1, 184) = 11.14$, $p = .001$. Pairwise comparison showed that participants in pixel group significantly estimated the time period earlier than those in vector group ($\Delta = 3.28$, $p = .001$). In addition, there was a statistically significant interaction between art style and gender on temporal estimation for situation No.6, whilst controlling for age, $F(1, 184) = 8.55$, $p = .004$. The simple main effect of art style was statistically significant in the males, $F(1, 84) = 18.8$, $p < .001$, but not in the females $(1, 99) = .07$, $p = .786$. Pairwise comparison shows that male participants in pixel group significantly estimated the time period earlier than male participants in vector group ($\Delta = 4.41$, $p < .001$). In addition, in situation No.2 and No.5, the main effect of art style did not show a statistically significant result, however, both of them showed a tendency of pixel art style being estimated earlier than vector art style, close to a significant level (situation No.2: $F(1, 184) = 3.57$, $p = .060$, situation No.5: $F(1, 184) = 3.40$, $p = .067$). In summary, 5 of the 6 situations yielded results showing that participants in

Table 6: Examples in the free comment answers in Question (2) of Experiment B

Situation	Answer examples	
1	Frequent words	Date, love, romance, anniversary, toast, beautiful, couple, wife, celebration, etc.
	Imaginative answer example	"My wife and I toasting our commitment."
2	Frequent words	Family, tradition, together, holiday, happy, delicious, laughter, etc.
	Imaginative answer example	"Before my children left home when children & their family come to visit holiday seasons."
3	Frequent words	Couch, food, calm, lonely, drinking, alcohol, single, etc.
	Imaginative answer example	"Eating alone in quarantine. Covid, loneliness, fear, anxiety, wishing things could be different."
4	Frequent words	Breakfast, newspaper, rude, coffee, disconnected, brunch, morning, work, etc.
	Imaginative answer example	"Father and son, son with cellphone, eating, talking at same time to get dad's attention but not pushing it."
5	Frequent words	Picnic, family, childhood, sunshine, outside, peaceful, kids, nature, etc.
	Imaginative answer example	"Picnic, happy, loving family, marriage, kids, this picture makes me think of the future and the possibilities of it."
6	Frequent words	Friends, joy, barbeque, family, teens, Asian food, group, fun, etc.
	Imaginative answer example	"Classic Chinese hot pot! I love it, one of my favorites. I would still go if we had one here."

the pixel group significantly estimated the time period of the situation earlier than the vector group, with 3 being statistically significant and 2 being close to significant. Gender's main effect was found in one of the situations and the interaction between gender and art style was found in another one of the situations. Therefore, null hypotheses were rejected, *H*3 was partially accepted.

3) Imagination:

Table 6 presents a selection of typical responses to Question (2). The column labeled "Frequent Words" displays the words that appeared most frequently in the answers. In contrast, the column labeled "Imaginative Answer Examples" provides examples of responses that were particularly distinctive and imaginative, and thus may be considered as indicative of a higher level of imaginative thinking.

In thematic analysis, it was observed that participant's free comments on the 2nd question could be categorized using 7 themes, shown in Table 7. Each theme represents a different level in imagination. The 1st theme was named "1_Basic", it was recorded when the answer includes descriptions about the basic cues in the situation. For example, in situation No.1, if a participant's answer included descriptions like "a couple is having dinner", it is considered a very basic and obvious statement on the basic cues, indicating the persons and event in the situation. The imagination level is considered lowest in this theme. The 2nd theme was named "2_Adjective". It was recorded when adjectives that modify the basic cues were seen in the comments. For example, in situation No.1, a participant used "formal" to describe the "dress" seen in the illustration, it was counted under the theme of "2_Adjective". These adjectives do not express much emotions or imagination. The 3rd theme was named 3_Emotional to record any emotional expressions. For instance, "romantic", "happy" were counted as emotions in situation No.1. The 4th theme is 4_Concept. When participants associated any abstract concept, like "marriage", "commitment" from situation No.1, they were counted as concept. The 5th theme was named "5_Storytelling". This is when participants started adding their own estimation or imagination to the situation. For instance, in situation No.1, although it was not indicated, some participants wrote "they are having a first date". The 6th theme is "6_Personal". It was recorded when the comment included participant's personal past experience that being recalled. The last theme was named "7_Imaginary", it was counted when participants started describing their imaginary objects or persons that do not even exist in the illustration.

Table 7: Coding in the thematic analysis for Question (2) of Experiment B

Theme	Explanation (examples in situation 1)
1_Basic	Words that describe situation's basic cues, e.g., "A couple is having dinner", etc.
2_Adjective	Words that modify the basic cues, e.g., "formal dress", "handsome", etc.
3_Emotional	Words that describe the evoked emotions of the participants, e.g., "I feel romantic", "happy", etc.
4_Concept	Words that describe an abstract concept associated from the situation, e.g., "marriage", "commitment", etc.
5_Storytelling	Participants started telling stories containing information beyond the basic cues, e.g., "they are having a first date", etc.
6_Personal	Participants started describing their personal experience, e.g., "when I was dating my wife", etc.
7_Imaginary	Participants started purely imagining objects that do not exist in the illustration, e.g., "candle", "children", "sparkle", etc.

Table 8: Summary of the results of thematic analysis

No.		1B	2A	3E	4C	5S	6P	7I
1	Pixel	52	18	29	26	7	9	1
	Vector	56	19	29	29	3	9	7
2	Pixel	66	12	18	18	6	7	5
	Vector	81	11	22	34	6	7	5
3	Pixel	55	11	17	13	6	4	33
	Vector	49	7	33	17	20	8	7
4	Pixel	60	9	13	17	4	1	3
	Vector	49	23	13	19	5	2	5
5	Pixel	73	23	14	10	2	7	7
	Vector	73	16	19	11	1	7	6
6	Pixel	69	22	17	10	2	3	1
	Vector	75	17	10	14	2	9	1

The numbers represent the frequency of each theme appeared in the answers in pixel and vector group in each situation.
"No." on the left column means the situation No.
The header from "1B" to "7I" represent the 7 themes.

The results of thematic analysis for each dining situation are summarized in Table 8. The total responses for pixel and vector group are 94 and 95 respectively, the numbers in Table 8 represents the frequency of each theme in the responses. In general, "1_Basic" was found in the majority of participants' comments, with approximately 50%−80% (minimum 49 responses to maximum 81 responses among 90+ total participants) participants mentioned in the comments. Following is "2_Adjective", "3_Emotional" and "4_Concept", with between 10% to 30% (minimum 9 responses to maximum 34 responses among 90+ total participants) participants mentioned. In the end, "5_Storytelling", "6_Personal" and "7_Imaginary" were barely found, less than 10% (basically single digit responses) in all situations, except for situation No.3, with "5_Storytelling" being found in more than 20% (20 responses in 95 total participants) participant's comments in the vector group, and "7_Imaginary" being found in more than 30% (33 responses among 94 total participants) participant's comments in the pixel group.

4) Correlation between temporal estimation and preferences on pixel art / video games:

Table 9 displays the results of the correlation analysis conducted to examine the potential relationship between temporal estimation and participants' preferences for video games and pixel art style (Questions 3, 4, and 5 in Experiment B). The results of the analysis indicate that there was no significant correlation found between the level of preference for pixel art style in video games and the accuracy of temporal estimation.

Table 9: Summary of the correlation analysis between temporal estimation and preferences for video games and pixel art style in pixel group

Variable A	Variable B	Situation No.	Correlations between Variable A & B	
			r	p
Temporal estimation	Preference on video games	1	-.05	.64
		2	.08	.44
		3	.08	.44
		4	-.04	.66
		5	.04	.73
		6	-.14	.16
Temporal estimation	Preference on pixel art in video games	1	.05	.63
		2	.10	.30
		3	.07	.46
		4	-.02	.83
		5	.10	.30
		6	<.01	1
Temporal estimation	Preference on pixel art in general	1	-.05	.62
		2	.12	.23
		3	.02	.81
		4	-.05	.63
		5	.05	.65
		6	-.11	.27

3.6 Discussion

*H*3 was partially supported, showing that pixel art style affected participant's temporal estimation, in a way of making the visualized situation seem to be happening in an earlier time period. This could be called "the pixel art style effect". The significant differences were found in 3 of the 6 situations, and 2 situations with tendencies that were very close to significant. Among these 5 of the 6 illustrations, all of them showed that the pixel version of the situation looked earlier in time period, making it a strong case for "the pixel art style effect". For gender effect, only situation No.2 appeared to be earlier in time period for females than males, regardless of the art style. Finally, in situation No.6, there was an interaction that the "pixel art style effect" was stronger in males than females.

The only exception for "the pixel art style effect" was situation No.1, "dinner dating with partner". The characteristics of situation No.1 might be very time-specific, strongly affecting participant's temporal estimation of the situation regardless of the art style. On the other hand, the rest of the other dining situations do not have the time-specific feature, therefore the art style could play a bigger role and affect their temporal estimation strongly enough to show a significant difference. However, the reason why

this "dinner dating with partner" situation is time specific is still just a hypothesis that needs to be further explored.

Experiment B successfully discovered the phenomenon that pixel art style could affect people's temporal estimation on a visualized situation. In the follow-up correlation analysis on the relationship between temporal estimation and the preferences on video games/pixel art style, no significant correlation was found between the preference on pixel art style (video games) and the estimation of time period. The general impression of "retro" and "nostalgia" on pixel art style might played a role in affecting participants' cognition subconsciously. However, there was no evidence in this experiment to prove this point. Pixel art style's abstract, blurry visual might be a key factor that influence our perception. Further investigations are needed to explore the actual reasons behind this phenomenon.

For imagination, there was no noticeable findings to prove that pixel art style could trigger more imagination. Among the themes in thematic analysis, the last 3 themes are considered comments with higher level of imagination. In situation No.3 (a man sitting on the couch drinking alone), there were obviously more people in the pixel group described more imaginary items, while there were slightly more people in the vector group trying to tell a story. Since this is the only dining situation with only 1 person in it, it might involve participant's imagination in a different way. Other than this finding, there was not enough observations to provide any conclusion.

4. CONCLUSION

It is widely known in the game industry that pixel art style would make a game look more "retro" and "nostalgic". However, these feelings are not clearly explored and defined. In general, a retro game usually means it is made in the past era, it is an "old" game. It does not necessarily mean we also think what is happening in the game is also in a past era. However, in this study, it is found that simply by pixelating the dots and lines of a dining situation sketch, the pixel art style could affect temporal estimation, trick people to believe that the situation is happening in an earlier time period. This might lead to older people feeling easier to picture themselves being in the situation. Designers and illustrators should take advantage of this phenomenon in game design and media graphic design. Researchers are recommended to conduct future studies to explore this phenomenon.

The "retro" characteristic of pixel art style does not simply mean that the content looks like being made in a past era, it might also influence what we comprehend on the "story" of the content. However, the mechanism behind this effect still remains unclear. Situations with stronger time-specific contents might be immune to this effect.

There is no clear evidence that pixel art style could stimulate more imagination and "fill the gaps/blank" compared to vector art style. The simplicity of the visuals might be a more important factor. A situation with only 1 person in it might connect to our imagination in a different way and has a potential to be affected by art style. This needs to be further discussed in experiment using pixel art style and vector art style with different level of simplicity, and the number of persons in a situation is an interesting topic.

5. LIMITATIONS

One limitation of this study is that it focused solely on the dining situation. This was due in part to the fact that dining situations have been relatively well-studied in the past and there are established visual representations of this context that can be used in experiments. However, this limitation also means that the findings may not generalize to other social situations that have not been as extensively studied. On the other hand, regarding studies on pixel art style, visualized situation is only one of the many approaches. It may be valuable to expand the study of pixel art style in video game design, poster design, commercial design, and other real-world applications.

Another limitation of the study is that the levels of imagination were created solely based on observing the raw data obtained from Experiment B, which did not yield effective results. Therefore, it is necessary to develop better methods to comprehend the levels of imagination in a more structured manner.

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NOTES

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Suomiya BAO (Member)

Suomiya Bao is an Assistant Professor at Institute of Art and Design, University of Tsukuba. He got his Ph.D. in Kansei Science from the Doctoral Program in Kansei, Behavioral and Brain Sciences, School of Comprehensive Human Sciences, University of Tsukuba. He also has 2 years of experience working as a full-time designer at Tadano, Ltd. His research interest includes User Experience, Player Experience, Game Design, Gamification, Kansei Engineering, Design Psychology, Consumer behavior, Arts and Humanities, Computer Graphics and Human-computer Multi-sensory Interaction.