Examining the Influence of Visual Stimuli and Personal Characteristics on Users' Willingness-to-Wait Time and Waiting Patterns

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Abstract. Waiting is inevitable in many interaction scenarios. Prior research suggests that waiting experience is associated with factors at both individual and contextual levels. This paper reports an experiment study examining the influence of visual stimuli and personal characteristics on users' waiting behavior. Our results show that higher delayed gratification (individual) is associated with longer waiting duration and shorter strategy formation time. As for features of visual stimuli (contextual), rotating-bright loading icons lengthen time perception and discourage people from waiting. These results provide design implications such as personalized waiting duration and ways to create better waiting experience.

Keywords: Waiting · Delayed gratification · Loading icon · Time perception

1 Introduction

In many interaction scenarios, users have to wait before a preferred outcome occurs. For example, they may have to wait for a loading page when surfing the Internet, or they may need to keep a healthy but less-tasteful diet before any weight-loss. Their waiting behaviors are less understood. It is of great importance to understand what keeps users wait and what makes them give up, in order to effectively adjust waiting behavior in the right direction. Since waiting behaviors are determined by both individual-level dispositions (e.g. personal characteristics like delayed gratification [1]) and contextual inducements (e.g. environmental stimuli: the speed of countdown [2] & loading icon [3]) [4], this paper addresses the research questions from two aspects:

RQ1: How does personal characteristics, e.g. capacity of delayed gratification, influence users' waiting behavior?
RQ2: How does characteristics of the visual stimuli, e.g. movement status and level of illumination, influence users' waiting behavior?

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Waiting is a common phenomenon in everyday human-computer interaction (HCI) scenarios. The experience of waiting is an important part of perceived satisfaction of the service or software. Although the increased speed of Internet reduces the discomfort of waiting, in many situations, waiting is still inevitable and very likely unbearable to users. Therefore, providing a pleasant experience in users' waiting scenarios is an important topic for HCI.

Prior research has mostly focused on the effect of contextual-level factors on waiting [5–7], and we know little about how individual characteristics influence users' waiting behavior. In fact, the individual-level factors and contextual-level factors always coexist and interact with each other in real-life situations. Hence, in this study, we modify one paradigm to test the impacts of these factors in the same scenario, which enables us to examine the different influences induced by different factors. We also use a real-life waiting task to make the experiment more relatable to the users. Our study reveals how these two factors affect waiting (more specifically willingness-to-wait time and waiting patterns) and provides practical implications to interaction design.

The rest of paper is organized as follows: First we introduce related work which leads to our hypothesis; then we describe our experiment design in the methodology section. We then present our findings, followed by conclusion and implications for design.

2 Related Research and Hypotheses Development

2.1 Waiting in Human-Computer Interaction

Previous research has paid close attention to the limits of how long people wait in different scenarios, and discovered ways to increase waiting time. For example, Nah found that the maximum waiting time is 2 s for a regular tasks [8]. While Nielson's research indicated that the waiting limits varied from 0.1–10 s which depended on the context (task) and attention [9], Galletta and others demonstrated that, after waiting 4 s, people's performance level dropped significantly. They also showed that 8 s was the watershed of attitude change [10]. Ceaparu and others found that when people watched mobile videos, waiting and preference were two main factors influencing user experience [11].

Some research focuses on the different forms of waiting stimuli on waiting durations. Passive, progressive and interactive screens are three most common types of loading screen in user interface [5]. They have different usage scenarios in which they serve different purposes. The passive loading screen, which is a cycle that rotates at a set speed, is usually used when the waiting time is less than the progressive and interactive screens [6]. However, there is no standard for how fast the passive loading icon should rotate in order to create the best possible experience for the user. Other research explores certain features of waiting stimuli on waiting durations. For example, research shows that users' perception of time can be influenced by progressive function and loading duration of the loading symbol [7]. Furthermore Kim and colleagues tested several different types of loading symbols in their study and indeed found that a waiting symbol designed according to tested guidelines reduced the users perceived waiting time.

2.2 Individual Level: Delayed Gratification

In most cases, waiting is a process of delayed gratification, which means people wait to pursue valuable long-run rewards instead of small short-run ones [12]. For a long time, researchers believe that waiting duration is determined by a relatively stable personal characteristic: capacity of delayed gratification (future-oriented self-control) [13, 14]. The most famous experiment about waiting and delayed gratification is the marshmallow experiment conducted by Mischel [15]. Research following this work suggests that delayed gratification was a relatively stable personal characteristic which could predict performance of adults based on their childhood behavior [16]. Research shows that people with higher capacity of delayed gratification are more patient and less impulsive [17]. The neural mechanism of delayed gratification also proves its stability [18].

Delayed gratification is made up of two parts: (1) delay choice (the choice phase that selects between an immediate reward and a delayed one); (2) delay maintenance (the waiting phase that the participant keeps the choice of delayed gratification while the immediate reward is still available) [19]. Similarly, waiting behavior consists of a choice phase and a the maintenance phase. The length of maintenance phase reflects the willingness of participants to wait for the reward. People wait longer for larger preferred rewards have higher capacity of delayed gratification. Thus, our first hypothesis is:

H1: Higher capacity of delayed gratification is associated with longer willingness-to-wait time (WTW).

2.3 Contextual Level: Visual Stimuli

Recent psychology research has recognized the influence of environment on waiting behavior [14]. Taking the interaction with complex environment into account, waiting behaviors are regarded as a value-based decision-making process [17]. In other words, users' waiting-or-not decision is a calculated cost-benefit analysis. People learn about the environment from repeated interaction and adjust their waiting behavior after calculating their benefits and costs [12]. The most obvious cost of waiting is the consumption of time. Waiting for a reward is at the cost of time to get other potential rewards. The new interpretation of waiting offers the possibility to change or cultivate people's waiting behavior through the distortion of subjective time perception. Söderström and his colleagues conducted an exploratory study and found that different speeds on loading screens led to the changes of participants' time perception. Specifically, the more quickly loading screen rotated, the faster the participants' felt time passed by [3].

Time perception is influenced by many factors. Research has found that the movement status and level of illumination have great impact on time perception [20]. For movement, research found that moving or flickering visual stimuli are typically judged longer than static ones using temporal reproduction method [21, 22]. Kanai and other psychologists further revealed that the temporal frequency of a visual stimulus was the only factor that could distort time perception [23]. Serving as the "clock" of perceived duration, faster temporal frequency of stimuli (e.g. rotating more times in a second) can speed up people's inner clock and thus elongate the subjective time perception, making them less willing to wait. Higher intensity illumination also increases subjective time duration [24]. Goldstone and colleagues found that when judging the duration of red lights, participants always chose the bright stimuli as the longer duration, comparing to standard light dim.

Therefore, our hypotheses on visual stimuli are:

H2a: The waiting time with rotating stimuli is shorter than static ones.
H2b: The waiting time with brighter stimuli is shorter than darker ones.

In conclusion, delayed gratification—seen as a stable personal characteristic—may shift the waiting duration or shape waiting patterns in a general level. When it comes to the opinion of value-based decision, waiting is changed through trial-by-trial accumulation. Hence, it is also important to analyze the effect of delayed gratification and features of visual stimuli in different levels.

3 Methods

3.1 Tasks and Participants

We design our experiment under McGuire and Kable's delayed gratification paradigm [12]. 24 participants were asked to perform a series of task trials to harvest monetary rewards (virtual coins) in 20 min, and receive rewards based on the coins collected. The process of one trial is shown in Fig. 1(a).

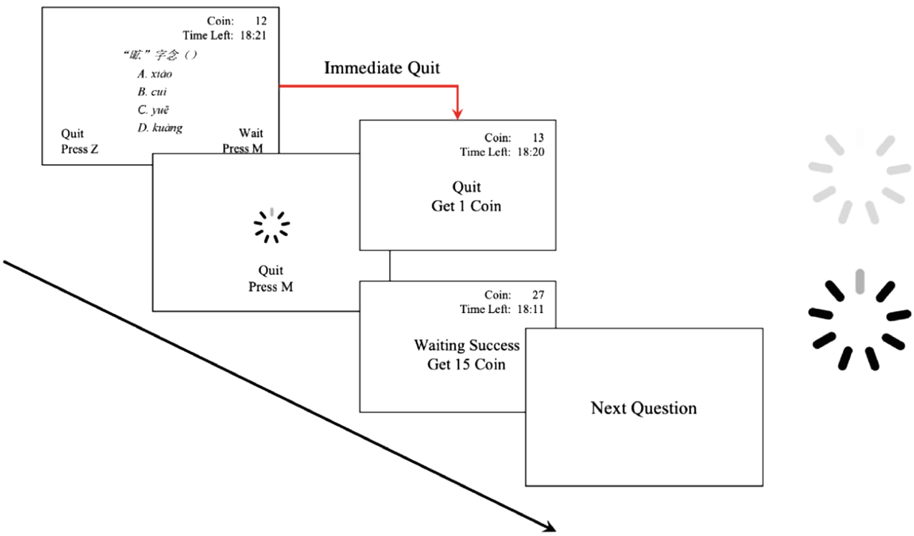

Fig. 1. (a) Left: Process of one trial (the waiting stimuli vary in different trials); (b) Right: Sample stimuli of different illuminations (Bright vs. Dark).

In each trial, participants encountered rare Chinese character recognition questions that they could not answer. They were faced with two options: quitting immediately to receive 1 coin at the cost of 1 s (the immediate reward choice), or waiting for the search result to get 15 coins at the cost of a random length of time (the delayed reward choice). The predefined waiting time followed a truncated generalized Pareto distribution, which was considered as the default distribution of an unknown environment (see Fig. 2) [12]. While waiting, they could change their minds and quit at any time and receive 1 coin. In the process of waiting, 4 different visual stimuli (moving/rotating vs. statics and bright vs. dark) and blank screen (baseline) were randomly shown on the display (see Fig. 1(b)). The temporal frequency of rotating stimuli was 6 Hz. For illuminance, the average gray value of bright stimuli was 251 (0–255, 0 was black while 255 was white); for darker was 233.1.

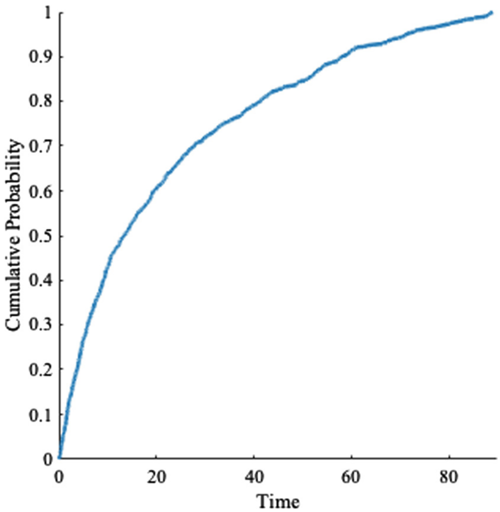

Fig. 2. Cumulative Probability of truncated generalized Pareto distribution ($k = 2, \sigma = 20,\ \theta = 0$, truncated at 90 s)

Participants were instructed the rules of the waiting game by the experimenter before performing and also informed that the stimuli were randomly displayed on the screen. They were also given a same 20-s task as practice to ensure their correct understanding of the rules. Head support was used to ensure that participants kept looking at the center of the screen in the process. After the task, they completed translated delayed gratification inventory (DGI) [25] and were given a short post-session interview about their waiting strategy during the whole task for the reference of further data analysis. DGI had good reliability and validity.

The predefined waiting time followed a truncated generalized Pareto distribution ($k = 2,\ \sigma = 20,\ \theta = 0$,, truncated at 90 s), whose quartile upper boundaries were 4.31, 12.81, 30.56, 89.78. Instead of randomly sampled on each trial, waiting time was sampled from each quartile in random sequence before a quartile is repeated to reduce the within-condition variability at the cost of slight sequential structure of waiting time.

3.2 Experimental Design

We used a within subject design with 2 (movement) × 2 (illumination) experimental conditions and a control condition. These 5 conditions were randomly distributed to each choose-to-wait trials.

To ensure enough trials in each conditions, the experimental duration was set to 20 valid minutes, which only included the time that quitting costs and waiting consumes. The feedback and skip screens did not count in the consumed time. The question screen did not count in the consumed time, which allowed participants to think and have short breaks during the long task.

Time left to complete and total coin were shown on the upper right screen all the time except during the waiting process.

3.3 Data Collection and Analysis

24 Participants were recruited in the experiment and finished the task. Data from 23 valid participants (10 males, mean age = 20.35, SD = 2.27) are used for further analysis. There was also one subject that only keeps 600-s length of record due to the mistakenly hitting the 'ESC' key, yet we kept the data in this analysis since it does not change his willingness-to-wait time (WTW).

There were two waiting phases on each trial: (1) the delay choice phase (when deciding to wait or not, people choose between the exploitation of certain strategy and exploration of an unknown environment); (2) the delay maintenance phase (people adapt their willingness-to-wait time based on the continuously updating information with the interaction of environment). Therefore, we also analyzed participants' general waiting patterns in addition to WTW.

We analyzed WTW time from two aspects. At the individual level, we analyzed the correlation between DGI score and their WTW. At the contextual level, we tested whether different features of loading icon distort the time perception and thus lead to the difference of WTW. Therefore, we used 2 × 2 repeated measure ANOVA to measure the differences between illuminance and rotation speed.

As for waiting patterns, we analyzed the changes of waiting behavior as time elapsed. Regarding waiting as a continuous process allowed us to see how people emerge their waiting habits.

4 Results

4.1 Capacity of Delayed Gratification and Waiting Time

Finding 1: Higher capability of delayed gratification is related to longer waiting time. We examined the relation between the capacity of delayed gratification and participants' WTW. The former variable was measured by Delayed Gratification

Inventory [25]. As for the latter, we used the overall wait-and-quit trials that deleting outliers as average WTW, since these trials revealed participants' real WTW time on a certain trial.

We used quartiles method to remove outliers of each data in Matlab R2016b since the data did't follow normal distribution. The quartiles method eliminated data points that were more than 1.5 interquartile ranges (IQRs) below the first quartile (Q1) or above the third quartile (Q3), which was widely applied to abnormal distribution. The elimination of outliers was repeated till no more outlier.

Using SPSS 23.0, results showed that DGI score was positively related to average WTW in a marginally significate level (Spearman coefficient: $r = 0.392$, $p = 0.079 < .01$, 2-tailed).

4.2 Features of Visual Stimuli and Waiting Time

We extracted all wait-and-quit trials as valid ones to analyze whether people's WTW are influenced due to the distortion of time perception under different stimulus displays. In the preprocessing period, we also used quartile method to eliminate outliers. Then, we calculated the means of each condition for every participants as their WTW under different conditions.

Influences of Movement and Illumination on WTW. Finding 2a: Two features of stimulus, movement and illumination, influence people's waiting time: moving stimulus and brighter stimulus are related to shorter waiting duration.

To figure out whether stimuli in different movement and illumination status have a distinctive impact on people's WTW, we conducted a 2×2 repeated measure ANOVA to analyze the difference in SPSS 23.0. The descriptive statistics in each condition are shown in Table 1.

Table 1. Descriptive statistics of each condition ($M \pm SE$, $N = 23$)

	Bright	Dark	Blank
Rotating	5.734 (0.614)	6.120 (0.639)	6.692 (0.784)
Static	6.391 (0.608)	7.112 (0.817)	

The results showed that there was no significant interaction between movement and illumination ($F(1,22) = .267$, $p = .611 > .05$). And the main effect of movement and illumination were both significant (For movement: $F(1,22) = 8.261$, $p = .009 < .05$; For illumination: $F(1,22) = 5.665$, $p = .026 < .05$), confirming that the movement and illumination of the stimulus bias people's WTW. Specifically, the quicker the stimulus rotated and the brighter the stimulus displayed, the shorter participants were willing to wait (See Fig. 3).

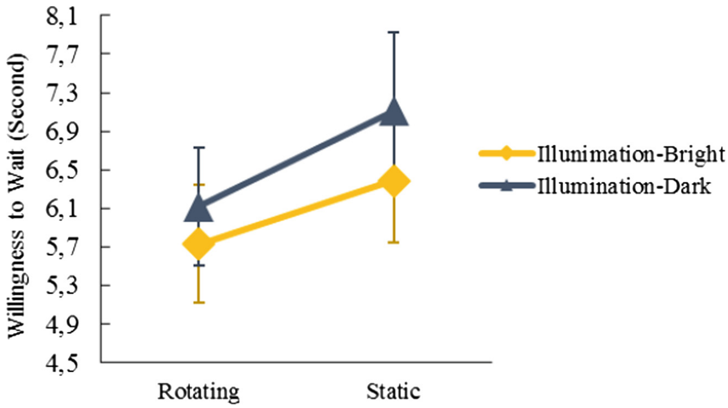

Fig. 3. Willingness to wait under different movement and illumination conditions (*M* ± *SE*)

Comparison of Experimental and Control Conditions on WTW. Finding 2b: Compared with blank screen, users are less willing to wait when faced with fast-moving bright stimulus, and more willing to wait under static and dark stimulus (see Fig. 4).

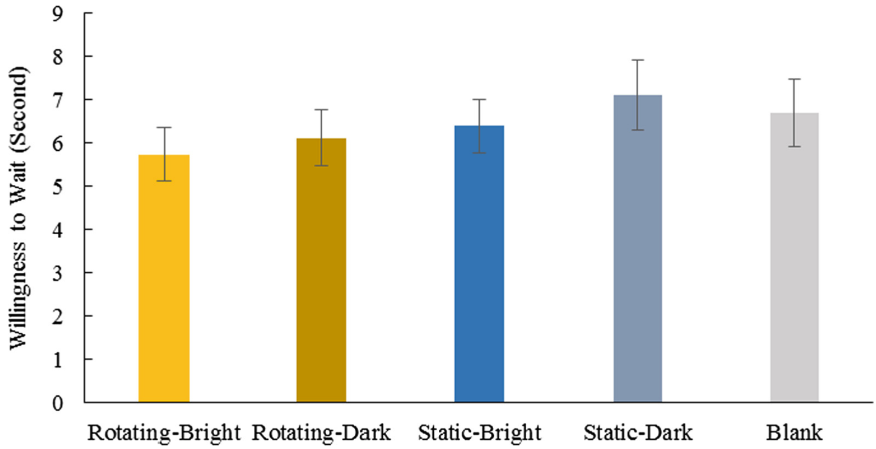

Fig. 4. Willingness to Wait under different stimulus displays (*M* ± *SE*).

Since stimulus do influence waiting time in a different way, it is meaningful to know whether people distinctively wait longer or shorter when waiting under such stimuli than a blank screen.

Hence, we separately compared each experimental condition with control one by using 1 × 5 repeated measure ANOVA. Results showed the main effect of experimental condition was significant ($F(4,88) = 3.481$, $p = .011 < .05$). Specially, that the rotating-brighter stimulus made WTW marginally shorter than blank screen (p = .077 < .1), and much more shorter than static loading icons (Rotating-Bright v.s. Static-Bright: p = .039 < .05; Rotating-Bright v.s. Static-Dark: p = .014 < .05) (see Fig. 4).

4.3 Waiting Patterns Analysis

General Waiting Patterns. Besides exploring specific behavior on each trials, we wanted to see people's waiting behavior in a bigger picture. Specifically, we were curious about if there were different patterns of waiting policy as time elapsed, which were both affected by people's innate waiting strategy and the interaction with environment.

Using Matlab R2016b to draw scatter diagrams of waiting time on each trial as time elapsed, we could directly see 3 distinctive patterns of waiting policy (Fig. 5 presents representative patterns of all participants).

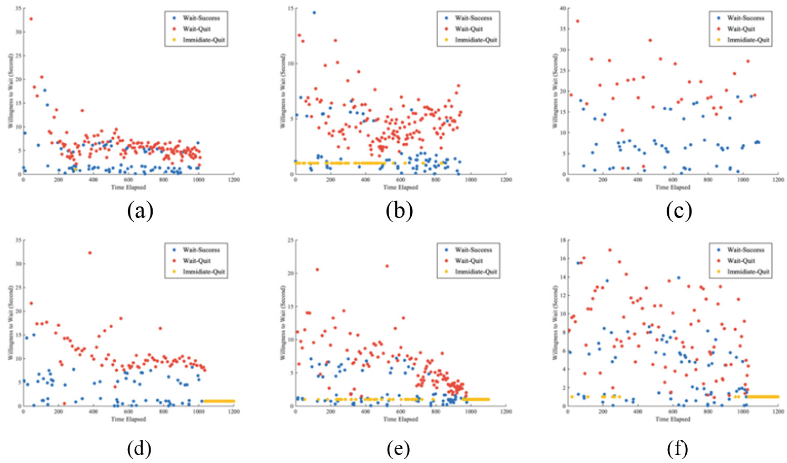

Fig. 5. (a) Pattern 1: Exploration; (b) Pattern 2: Hybrid; (c) Pattern 3: No strategy; (d), (e), (f) Variants of a, b, c. (Blue points: Wait-success trials; Red: Wait-quit trials; Yellow: Immediate-quit trials) (Color figure online)

Pattern 1. Exploration: The distinctive features of exploration waiting pattern are (1) participants seldom take the immediate quitting as their choice, which means they are more willing to explore and interact with the unknown environment; (2) participants can calibrate their waiting duration as time elapsed and settle the waiting limit to maximize their benefits of waiting. The exemplary pattern is demonstrated in Fig. 4(a).

Pattern 2. Hybrid. The significant feature of such pattern is repeated switches between waiting and immediate quitting (see in Fig. 4(b)). Some of them can adapt their waiting limit after the periodic exploration of waiting.

Pattern 3. No strategy. Not all data has an obvious pattern of waiting strategy. Some scatter diagrams show that the participants do not establish a waiting limit during the task, and thus we conclude them as no strategy (see in Fig. 4(c)).

Variants of Pattern 1 and 2 and No Strategy. Some data shown a drastic change by the end of the task: some people just quitted what they had done before and chose to quit immediately instead (see Fig. 4(d), (e), (f)). Such phenomenon occur in all patterns yet the beginning point varies.

The difference between pattern 1 and 2 is the different ratio of explorations to exploitations. Exploitation refers to the action of skipping to obtain 1 coin, which is the obvious and fixed strategy in this experiment. On the other hand, exploration means the actions to interact with environment with more uncertainty. People with pattern 1 are more willing to deal with uncertainty while people with pattern 2 are relatively more conservative that they stick to exploitation strategy for most of time and still distribute some to make exploration. These are two common patterns viewed in this experiment.

The variants of pattern 1, 2 & 3 reveals an interesting but common phenomena: people are more conservative and inclined to use exploitation strategy continuously under time pressure. Prior research show that people are less risky under high as compared with medium and low time pressure [26, 27]. Therefore, we believe that these three types are the variants of pattern 1, 2, & 3.

Strategy Fixation Point and Capacity of Delayed Gratification. Finding 3: Users with higher DGI have shorter exploration time and form waiting strategy more quickly.

It seemed that people formed their relatively fixed strategy during the process in a different speed. Some took a long time to establish their strategy, while other stuck to one shortly after the beginning of the task. Therefore, we explored what personal characteristics influence the strategy fixation time.

Again using valid wait-and-quit trials, we took each trial as a starting point and extract all trials within 50 s after this trial as the sample to calculate its coefficient of variation (CV) using Matlab 2016b. If there were more than 4 CV less than 0.15 of any five continuous CV, we regarded the starting trial as formation time of strategy. Using SPSS 23.0, results showed that DGI score was negatively related to the formation time in a significate level (Spearman coefficient: $r = -0.667$, $p = 0.018 < .05$, 2-tailed).

5 Conclusion and Discussion

5.1 Summary and Interpretation of Findings

Inspired by two interpretations of waiting behavior, we examine the effect of delayed gratification and two features of visual stimuli (movement vs. illumination) on people's waiting-times and patterns.

Results confirm the effects of visual stimuli and capacity of delayed gratification on users' willingness-to-wait time. People with higher DGI score indeed voluntarily wait longer. Two features of visual stimuli, the bright and fast-rotating, also show the tendency to shorten our willingness-to-wait time. By examining the effect of different features of visual stimuli, our study suggests time perception may be an effective mediating variable that can change people's waiting behavior.

The influences of the capacity of delayed gratification on waiting behavior are two-fold: (1) Good capacity of delayed gratification enhance waiting duration, helping to explore in depth; (2) yet users with high DGI tend to stick to quickly established strategy which prevent them from exploring more about the variation of complex environment in width.

5.2 Limitations and Future Work

There are some limitations of the experiment. First of all, different contrast of visual stimuli may have impact on time perception. One study do show that a reduction of apparent duration of a visual stimulus when an intermediate contrast test interval was briefly preceded by a high contrast context as compared to when preceded by a low contrast context [28]. The scale of time suppression of contrast happens in milliseconds, which may have slight influence even if contrast be the confound factors of this experiment. Secondly, visual stimuli with different illumination and moving speed may serve as the progressive information of waiting. For example, loading screens and indicators in the interface give the user an increased perceived performance for the software [29]. Besides, Jang and colleagues confirmed that the changing status of lightness exert informative effect on users' intuitive perception [30]. Stimuli used in this experiment are often put on the loading page to indicate the progress. Therefore, we cannot eliminate the effect that different types of stimuli have on informative status. However, the repeated scenario decreases the informative effect of visual stimuli because participants gradually realize that there are no information signaling the status of waiting process.

Our study, along with prior study conducted by Söderström and his colleagues [3], suggests the possibility of distortion of time perception in waiting. Future work may also consider improving waiting durations by changing the presentation mode of elapsed time in the screen.

5.3 Design Implications

The understanding of waiting behavior exert great impact not only on users, but also on designers across industry. Therefore, designers may have a relatively valid indicator of users' waiting preference and personalize waiting offer for different users based on their capacity of delayed gratification from their profiles and behavioral data.

Through a short inventory of delayed gratification, systems may predict users' willingness-to-wait time more accurately and roughly draw a general waiting pattern in a repeated waiting scenario.

In some situations when waiting is inevitable for user, designers may want to keep users waiting. For instance, the poor internet connections, the overloading of servers.

Under this circumstance, a more user-friendly waiting icons can be designed to shorten users' subjective time perception and help them wait for what they want in a more efficient way. For example, the loading icon may change its rotating speed according to the situation of internet connection to prevent unnecessary waiting. Or when users exercise in front of electrical devices, a better design that indicates waiting process may help them persist longer and thus beneficial for them.

While under other circumstances, advertisers or designers wish people to wait. Therefore, the design has to fool our perception which, is an extremely delicate operation. Our study provides the evidence of the temporal frequency (rotating speed) and illumination as effective tools to lie to users, which can be combined with informative widgets such as progress bar.

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