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Article

Behavioral Characteristics in Emergencies[1]: Comparison Before and After a Time Limit

Mayuko UEDA*, Kazushige WADA*, and Shinnosuke USUI**

The present study experimentally investigated human behavior in emergencies that cause high arousal levels. We focused primarily on comparing performances before and after a time limit. Participants carried out computer tasks of various levels of difficulty under three conditions: high arousal condition with a mock emergency situation; time pressure condition when only the time limit was displayed; and control condition which was the normal condition. Results indicated that participants were more likely to take action without regard for precision, before the time limit in the high arousal condition, compared to the other two conditions. On the other hand, participants improved their precision after the time limit compared to the time pressure condition. They were more likely to be thoughtful and engage in prompt action. This result suggests that seriousness, is one of the factors that constitute an emergency situation, maintained motivation of participants to continue their tasks.

key words: emergencies, high arousal, anxiety, time limit

Introduction

Work situations do not always happen in the same environment. Various emergencies are triggered by different events. In an emergency, even the tasks that can be easily conducted under normal conditions take time and procedural mistakes occur on a daily basis. According to the Yerkes–Dodson law, according to which, "there is an inverted U-shaped relationship between arousal level and performance. Performance decreases when levels of arousal are too high or too low" (Yerkes & Dodson, 1908). Performer's arousal level becomes too high in emergencies because of anxiety and stress from the environment. As a result, optimal performance becomes difficult to achieve.

Emergencies were experimentally investigated in the water tank study by Kano (1983). In this study, an apparatus comprising a wooden panel, a water tank, water pipes, and light bulbs were developed. The water tank was placed on top of the apparatus, such that water actually flowed out of the tank. Water pipes were assembled beneath the tank in a maze, such that water would go through the pipes and reach the light bulbs. The lights were set to turn on when the water reached them. There were square devices to change the water flow that were called water pipe junction switches that participants could use to change the path of the water flow by rotating them. Once the water reached a light bulb, it drained out from an open faucet that had been kept open from the start of the experiment in four minutes and forty seconds. Kano requested participants to turn off the lights by rotating the switches before the water drained from the tank. The emergency situation in this experiment was the draining of water from faucets, with the floor getting soaked with the passage of time as a consequence.

Kano's study indicated that the number of switch rotates per minute, and the number of switches used to complete a task increased significantly in an emergency, compared to a control task in which participants did the identical task presented on paper. This suggests that in an emergency situation, participants would unnecessarily rotate switches without careful thinking. Moreover, they might not use other switches that were critical for completing the task. Kano concluded that impulsive and thoughtless behaviors

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* Safety Research Institute, West Japan Railway Company, 1–2–12, Matsuzaki-cho, Abeno-ku, Osaka 545–0053, Japan
e-mail: mayuko-ueda2@westjr.co.jp
** Graduate School of Human Sciences, Osaka University, 1–2, Yamadaoka, Suita-shi, Osaka 565–0871, Japan

increased in emergencies. However, Kano used different apparatus for the control and emergency conditions of the study (a paper model and an actual model, respectively) and compared the same dependent variables, such as number of switches used in the two conditions, which reduced the reliability of the study. Moreover, Kano did not operationally define an emergency situation, but merely analyzed a condition consisting of water flow and a time limit, in which participant were in a hurry.

In the current study, we first defined an emergency situation and experimentally observed behavioral characteristics of emergencies. We developed a mock emergency situation in a laboratory setting, in which a computer-based water tank study task was assigned to participants. We hypothesized that a mock emergency situation would increase participants' arousal levels based on the Yerkes–Dodson law, which we referred to as the "high arousal condition".

We operationally defined an emergency situation by controlling two factors, "seriousness" and "time urgency." Seriousness is a factor in which a task performer can fully predict the criticality of an event and time urgency is a factor in which the task performer can fully recognize the time limit for dealing with the event. Many researchers have suggested that these factors are essential for defining an emergency (Abe, 1988; Hosoda & Inoue, 2000; Ikeda, 1986; Toda, 1992). Therefore, we observed behavioral characteristics in an emergency by assigning participants to carry out tasks in an environment involving these two variables.

We developed a time pressure condition and a control condition, in order to compare performance under a high arousal condition defined as a mock emergency situation. Time urgency was incorporated into the procedure in the time pressure condition. On the other hand, neither time urgency, nor seriousness was incorporated into the control condition, which was defined as a normal situation, as oppose to an emergency.

The high arousal condition in this study was designed to fit at the right end of the inverted U-shaped relationship described by Yerkes–Dodson law, in which high arousal greatly deviated from optimal performance represented by the lower right end of the curve. On the other hand, the control condition defined as a normal situation, in which the arousal level was hypothesized to be neither too high nor too low fitted at the top of the inversed U-shaped curve. Furthermore, the arousal level of the time pressure condition was assumed to be between the high arousal and time pressure conditions, such that it was located below the top of the inverted U-shaped curve, but above the high arousal condition. We compared participants' performance between these three conditions.

The second objective of the present study was to investigate differences in between behavioral characteristics before and after a time limit. We set this objective because in various work situations, individuals are assigned to complete a task within a certain time, whether or not it is an emergency. In such situations, individuals and organizations usually make an effort to complete their tasks as early as possible. However, it is always possible to fail to complete the tasks within the time limit. Possible reasons for this might be that the performer paid more attention to safety, or because the task was more difficult than expected. This suggests that factors influencing behavior, including goals and motivations might change significantly before and after the time limit. Moreover, behavior may also change as a consequence of the time limit. During an emergency, the degree of behavioral change might be highly significant. According to the definition of an emergency, both seriousness and time urgency factors affect one's behavior significantly before the time limit. The seriousness factor may continue to have a significant effect after the time limit, whereas the time urgency factor may have a weaker effect. We conducted this comparison because we believe that examining the differences in behavioral characteristics between before and after the time limit will help us prevent human error in the future.

Objectives

The first objective of this study was to experimentally observe behavioral characteristics of emergency situations that had been operationally defined. The second objective was to observe changes in behavioral characteristics in emergency situations before and after a time limit.

The present study examined the following hypotheses: 1. Behavioral characteristics in emergency situations before a time limit would follow the Yerkes–Dodson law and performance would decrease compared to control, time pressure, and high arousal conditions, in that order. 2. Time urgency in the high arousal condition would decrease and performance would improve after the time limit compared to that before the time limit.

Method

Participants

With the support of a temporary employment agency, 29 physically and mentally healthy men participated in the experiment (age range: 22–32 years old, average age: 24.3 years old). The participants had a visual acuity of 0.7 or better without glasses or contact lenses. Also, all were right handed. As a monetary reward for participation, participants received 10,000 yen. However, participants were informed in advance that the amount could be reduced up to 5,000 yen, depending on their experimental results.

Experimental task

Figure 1 shows the task used in this experiment. This figure shows the water pipe game, in which water was run from a water tank to a specified goal, displayed on a large monitor (Liquid Crystal Display LDT551 V by Mitsubishi). This task has been modified based on the experimental task used by Kano (1938). The contents of the task were nearly identical to our previous studies (Ueda, Wada & Usui, 2013; Ueda, Wada & Usui, 2015). We will explain the details below.

Description of the task As indicated in Figure 1, the water first flows into the water pipe from the water tank on top, the water then travels through different paths of water pipes and through the switchable quadrate water pipes (hereinafter referred to as "switch"), and finally flows out to the seven light bulbs, either red or yellow. There were four types of switches: oblique shaped, cross shaped, T-shaped, and L-shaped. By combining these 4 types of 23 switches, participants could change the direction of water flow. Water flow was displayed in light blue if the water was passing through and in black if it was not. Switches were designed to be rotated by a mouse click. Each single click made the switches rotate by 90 degrees. Participants needed to left click for a clockwise rotation and right click for a counter-clockwise rotation (There were also opposite cases because the setting was counterbalanced between participants). When participants interrupted and stopped the flow of water running from the water tank to the light bulbs by rotation the switches, lights were turned off and changed to dark gray. Although we presented the water pipe task with both red and yellow light bulbs at the start of different tasks, the number of lighting and the locations were different for each trial.

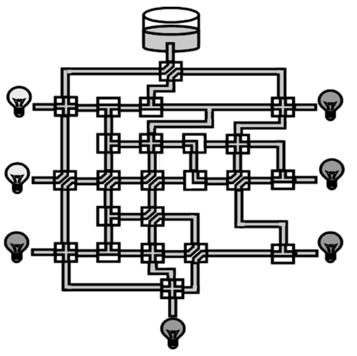

Figure 1 Example of the water pipe task

Task goal The goal of this task was to turn off all red lights while keeping yellow lights turned on. However, participants were instructed to try to use the switches as little as possible under any circumstances.

Levels of difficulty There were four levels of difficulty in this task. These levels were determined by the smallest possible number of times a task performer clicks to accomplish the goal (1 time/6 times/9 times/15 times). Also, the order of different levels of difficulty of the tasks was counterbalanced between participants.

Arousal conditions

In the present study the water pipe task under was conducted under three types of conditions: high arousal condition, time pressure condition, and control condition. Each condition is explained below.

High arousal condition (HA) By creating a mock emergency situation, we set the HA condition to fully represent the time urgency and seriousness factors. We instructed participants to try to complete the task within the time limit. However, if they could not complete the task within the time limit, they were required to continue working and complete the task. Each setting is explained below.

(a) Time limit display The time limit was displayed on a time limit counter on the bottom left part of the monitor in red. The countdown began after a one-second interval from 100 s. When the time reached 0, the display was automatically removed.

(b) Warning lights LED lights were turned on from the start of the task (International Organization for Standardization, 1996). Standards for flashlight coding (ISO11428: 1996) and for color stimuli (ISO11429: 1996) were used. The 100-s time limit was divided into 4 stages of 25 s and the frequency of flashing increased as the stage increased. In the final stage, the light kept flashing without a pause. Also, the color of the flashing light gradually changed in each stage from green, blue, yellow, and to red.

(c) Warning sound From the start of the experiment, a pure tone of 2 kHz (approx. 85 dB(A)) was presented. For auditory settings were conducted according to Mizutani, Matsuoka, & Komatsubara (1997) and Yamauchi, Takada, & Iwamiya (2003) in addition to the standard (JIS S 0013: 2011) of the Japanese Standards Association (JSA) (2011). The number of consecutive times and pause durations of auditory stimuli were synchronized with the flashing frequency and pause duration of visual stimuli.

(d) Warning wind A strong wind (wind speed: approx. 6.67 m/s) was presented using a large factory fan (TFZ-45SA by Trusco) 25 s before the time limit, based on a previous study, suggesting wind presentation increases arousal (Sakamoto, Nozawa, Tanaka, Mizuno, & Ide, 2006).

(e) Instruction for monetary reward Before starting the task, we informed participants that the monetary reward could be reduced from 10,000 yen up to 5,000 yen based on the average results of their 4 sets of HA performance. This was based on the findings of previous studies that a performance-dependent monetary reward causes pressure, and that an unstable reward system causes panic (Gray, 2004; Mintz, 1951). Although monetary reward in our previous study was 6,000 yen (Ueda et al., 2013), we increased the amount to 10,000 yen in order to better meet the requirements for seriousness, based on a previous study suggesting a higher monetary reward is more likely to cause anxiety than a lower reward (Mobbs, Hassabis, Seymour, Marchant, Weiskopf, Dolan & Frith, 2009). However, in fact, we disclosed the objective of the experiment at the debriefing after the experiment paid participants the full amount of 10,000 yen regardless of the results of their performance.

(f) Display of the number of clicks When participants clicked on the switches, the click number was displayed on a click counter at the right bottom of the monitor screen. This showed participants that the number of clicks was also used to determine their performance. By sequentially presenting an increasing number of clicks, we aimed to cause pressure that could reduce in the monetary reward.

Time pressure condition (TP) In the TP condition, only the display of the time limit was imposed on participants. The time limit was displayed in the same manner as the HA condition, but there were no warning lights, warning sounds, warning winds, instruction of monetary reward reduction, or a display of the number of clicks. However, similar to the HA condition, participants were instructed to try to complete the task within the time limit. If they could not complete the task within the time limit, they were required to continue working and complete the task.

Control condition (CT) This CT condition was perceived as the normal state. No conditions were imposed on participants, and there was neither a display of the time limit, warning signals, nor instructions of monetary reward reduction. Participants were allowed to take as long as they needed for the task. We instructed participants to think slowly and complete the task.

Procedure

First, the water pipe task was explained to participants, "The goal of the task is to turn off only the red lights. You can get higher points if you accomplish the goal with less switch presses, so please try your best to turn off the lights by rotating the switches a minimal number of times". Instructions in different conditions were as follows: In HA and TP, participants were instructed, "Please try to reach the goal as quickly as possible within the time limit. If you are unable to complete the task within the time limit, you may continue until you finish the task. However, finishing the task within the time limit is one of the factors for earning a good score. Your score would decrease significantly, after 100 seconds". In the HA condition participants were additionally instructed, "The monetary reward might decrease depending on your score". In CT, participants were instructed, "There is no time limit. You can take as long as you want, so think through and complete the task". After the instructions, participants practiced the task three times before starting the experimental trials.

This study had a within-participant design; therefore, each participant engaged in all three, HA, TP, and CP conditions, and engaged in all levels of difficulty, 1, 6, 9, and 15. The order of the three arousal and four levels of task difficulty were counterbalanced between participants. During the study, participants took a break for approximately five minutes after every four trials. The duration of the experiment was approximately 2 h, including the instructions, practice sessions, actual trials, and a debriefing after the experiment. Also, in all conditions, we instructed participants to continue working until they achieved the goal, regardless of whether there was a time limit, or not. However, if they could not achieve the task after 15 min (900 s), we regarded their performances as a failure and informed them to discontinue the task.

Results and discussion

The independent variables of the present study were arousal conditions (3 levels: HA/TP/CT) and levels of difficulty (4 levels: Level 1/Level 6/Level 9/Level 15). The dependent variables were time required to complete the tasks (hereinafter referred to as "necessary time"), the total number of clicks ("total clicks"), as well as the average idling time between clicks ("click interval times").

We separately analyzed the total clicks and click interval times before the time limit (0 to 100 s) and after the time limit (100 s to completion of the task).

First, we conducted a within participants, two-factor analysis of variance (Two-way ANOVA) on time (See Figure 2). Results indicated that the interaction between arousal conditions and levels of difficulty was significant (Levels of difficulty: $F(3, 84)=113.666$, $p<.001$; Interaction: $F(6, 168)=2.895$, $p<.05$). Since there was a significant difference in the interaction, we subsequently conducted a simple main effects test. Results indicated that the simple main effects of levels of difficulty were significant in all arousal conditions (HA: $F(3, 252)=26.053$, $p<.001$; TP: $F(3, 252)=58.532$, $p<.001$; CT: $F(3, 252)=48.445$, $p<.001$). Therefore, we conducted a multiple comparison. Results indicated significant differences in all combinations of difficulty levels (All: $p<.05$) in all arousal conditions, with the exception of the combination between 9 and 6 times. On the other hand, when the difficulty was Level 15, there was a significant difference in arousal ($F(2, 224)=8.038$, $p<.001$). So, we conducted a multiple comparison, which indicated significant differences between HA and TP, and between HA and CT (All: $p<.05$).

Figure 2 shows the results of the above analysis, it can be seen that in all the arousal conditions, participants took a longer time as the task became more difficult. Additionally, when the difficulty level of the task was Level 15, they took the shortest time in HA.

Results before the time limit

We analyzed the data before the time limit, from the start of the task up to 100 s. First, we conducted a two-way ANOVA among participants with total number of clicks as the depended variable (Figure 3). Moreover, results indicated the following significant and marginal differences: the main effect of arousal conditions, the main effect of levels of difficulty, and the interaction between arousal conditions and levels of difficulty (Arousal conditions: $F(2, 56)=14.939$, $p<.001$; Levels of difficulty: $F(3, 84)=95.131$, $p<.001$; Interaction: $F(6, 168)=1.907$, $p<.10$). Since a marginal difference was observed in the interaction, we subsequently conducted a simple main effect test and found significant differences of levels of difficulty in all arousal conditions (HA: $F(3, 252)=39.553$, $p<.001$; TP: $F(3, 252)=25.338$, $p<.001$, CT: $F(3, 252)=19.268$, $p<.001$). There-

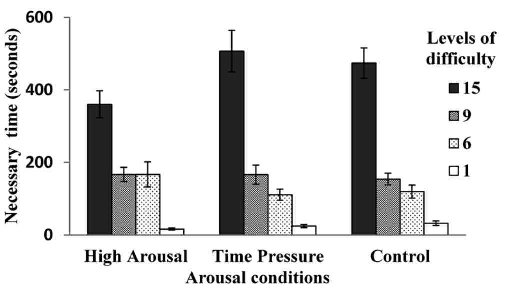

Figure 2　Time needed for the task

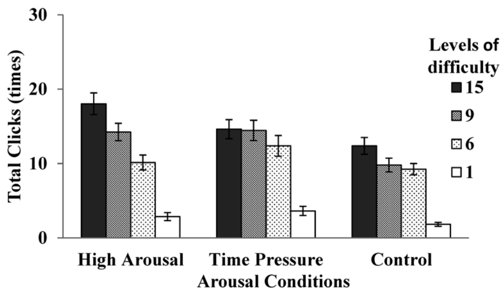

Figure 3　Total clicks (before the time limit)

fore, we conducted a multiple comparison, which indicated that significant differences between all levels of difficulty were found in HA. Similarly, significant differences between the difficulty at Level 1 time and other levels 6, 9, and 15 were found in TP and CT (All: $p < .05$). On the other hand, when the difficulty levels were 15 and 9, the simple main effects of arousal conditions were significant (Level 15: $F(2, 224) = 7.637$, $p < .001$; 9 times: $F(2, 224) = 6.514$, $p < .005$). Therefore, we conducted a multiple comparison, which indicated that when the difficulty level was 15, significant differences were found between HA and TP and between HA and CT. Moreover, when the difficulty level was 9 times, significant differences were found between HA and CT and between TP and CT (All: $p < .05$).

As can be seen in Figure 3, in all arousal conditions, the number of clicks increased as the level of difficulty increased. Additionally, when the difficulty levels were 15 and 9, the number of clicks increased as the arousal condition increased in severity starting from CT to TP and then to HA.

Next, we conducted within subjects two-way ANOVA on click interval times (See Figure 4) similar to the above analysis. When the difficulty was Level 1, the total number of clicks was less likely to exceed 10 times due to the easiness of the task, compared to other levels of difficulty (See Figure 3). Click interval time is the average time of click intervals. Accordingly, when there are only a few numbers of clicks, and it is impossible to obtain an accurate value. Therefore, we deleted the data of the difficulty Level 1 time and conducted the same analysis. The results indicated that the main effect of the arousal conditions was significant ($F(2, 56) = 17.292$, $p < .001$). We subsequently conducted a multiple comparison, which indicated a significant difference between HA and CT, and between TP and CT (All: $p < .001$).

As can be seen in Figure 4, there were not changes in the click interval times, even when the task became more difficult. Additionally, the results revealed that participants had shorter click intervals as the arousal condition became more severe.

Results after the time limit

We also analyzed the data from 100 s to the completion of the task (See Figure 5). First, we conducted a within subjects two-way ANOVA on total clicks, similar to the pre-time limit analysis. In this analysis, unlike the results before the time limit, a significant difference was observed only in the main effect of the difficulty level ($F(3, 84) = 61.892$, $p < .001$). We subsequently conducted a multiple comparison, which indicated a significant difference in all combinations of difficulty levels (All: $p < .05$), with the exception of the combination between 9 times and 6 times.

As can be seen from Figure 5, we first found that participants increased total clicks as the task became more difficult. We also found that different arousal conditions did not affect the number of clicks.

Next, we conducted within subjects two-way ANOVA on click intervals (See Figure 6), similar to the previous analysis. However, to conduct the anal-

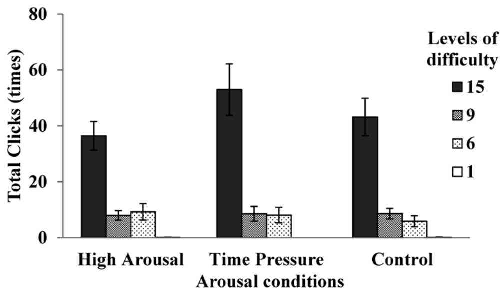

Figure 5 Total clicks (after the time limit)

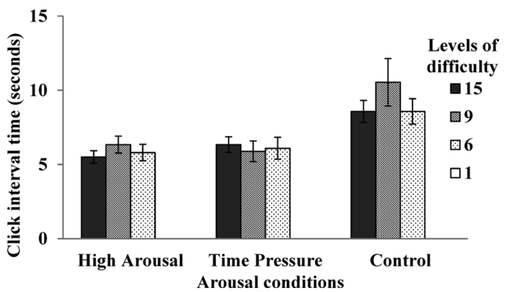

Figure 4 Click interval time (before the time limit)

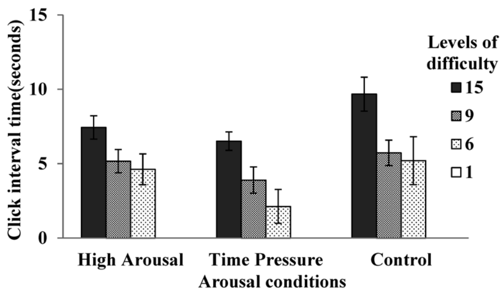

Figure 6 Click interval time (after the time limit)

Table 1 Results of ANOVA

Dependent variable	Factor	F	p
Time needed for the task (Figure 2)	Arousal conditions	$F(2, 56)=0.826$	
	Levels of difficulty	$F(3, 84)=113.666$	****
	Interaction	$F(6, 168)=2.895$	*
Total clicks (before the time limit) (Figure 3)	Arousal conditions	$F(2, 56)=14.939$	****
	Levels of difficulty	$F(3, 84)=95.131$	****
	Interaction	$F(6, 168)=1.907$	+
Click interval time (before the time limit) (Figure 4)	Arousal conditions	$F(2, 56)=17.292$	****
	Levels of difficulty	$F(2, 56)=1.255$	
	Interaction	$F(4, 112)=0.840$	
Total clicks (after the time limit) (Figure 5)	Arousal conditions	$F(2, 56)=1.541$	
	Levels of difficulty	$F(3, 84)=61.892$	****
	Interaction	$F(6, 168)=1.163$	
Click interval time (after the time limit) (Figure 6)	Arousal conditions	$F(2, 56)=5.550$	**
	Levels of difficulty	$F(2, 56)=16.519$	****
	Interaction	$F(4, 112)=0.395$	

+ $p<.10$, * $p<.05$, ** $p<.01$, *** $p<.005$, **** $p<.001$

ysis, we deleted the data of difficulty Level 1, similar to the analysis of click intervals, before the time limit. Results indicated that unlike the results before the time limit, the main effect of difficulty was also significant in addition to the main effect of arousal: Arousal condition ($F(2, 56)=5.550$, $p<.01$; Levels of difficulty: $F(2, 56)=16.519$, $p<.001$). Therefore, we conducted a comparison analysis for each main effect, which indicated significant differences in arousal conditions between HA and TP, and between TP and CT (All: $p<.05$). Similarly, significant differences in levels of difficulty were observed between Level 15 and 9 and between Level 15 and 6 (All: $p<.05$).

As can be seen in Figure 6, click intervals increased in duration as the task became more difficult. Additionally, participants had the shortest click interval times in TP. Results of the ANOVA are shown in Table 1.

Discussion of data before the time limit

The data analysis before the time limit indicated that necessary time and total clicks increased as the level of difficulty increased. This finding was not a surprising because we manipulated the difficulty levels by the smallest possible number of times a task performer clicks to accomplish the goal. These results indicate that the levels of difficulty were appropriate.

As the arousal condition became more severe, the number of clicks increased and click intervals became shorter. Click intervals refers to the idling time between clicks. This idling time can be regarded as thinking time when participants are not engaged in any behavior, but are thinking about things such as which direction should they rotate which switch, or which water flow should they stop to turn off the red lamp. These analysis results show that despite our instruction to click as little as possible, participants still clicked more and spent less time thinking just by being in a different environment, which was likely increase their arousal level.

In contrast, the levels of difficulty had no major effects on click intervals. This result is incongruent with those shown in Figure 3. However, this difference might have been caused by more participants completing the task within the time limit at lower difficulty levels. Moreover, the time limit of 100 s might have been too short to detect subtle differences in difficulty, considering that difficulty level did not affect the click interval. As the task difficulty increased and after clicking a certain number of times, participants might have realized that they needed to think carefully. Therefore, it is possible that apparatus used in the present study and the level of task difficulty that was used did not affect the duration of click intervals.

These results describe similar tendencies to our previous study (Ueda et al., 2013), which is indicative of the robustness of behavioral characteristics about performance before the time limit described above.

Discussion of data after the time limit

Results after the time limit indicated that participants increased the number of clicks as the task became more difficult. This result was in line with the results before the time limit, confirming again that the levels of difficulty were appropriate. However, other results were completely different from the results before the time limit. To find out the cause, it is necessary to examine previous studies and other data in more detail. Here we will only sum up the differences in results between before and after the time limit and further discuss the findings in the following Comprehensive Discussion.

First, as the task became more difficult, participants had longer click intervals, as the level of difficulty increased; participants were increasingly required to manipulate an increasingly complicated flow of water and rotate of switches. Therefore, it seems natural for them to increase their thinking time, as they were working by trial and error. However, this tendency was only observed in the behavior after the time limit. Before the time limit, there were no changes in click intervals resulting from different task levels.

Click intervals in TP were shorter, implying that in TP, people spend the least amount of time for thinking. This tendency was observed only for after the limit. Therefore, we concluded that difficulty levels and arousal conditions were highly likely to have different mental effects on participants' before and after the time limit.

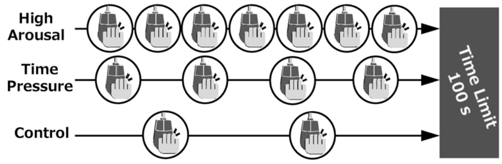

Figure 7 Performance model before time limit

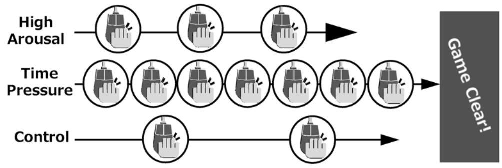

Figure 8 Performance model after time limit

Comprehensive discussion

First, we found that arousal conditions had different effects before and after the time limit, even in the performance of the same participant. The analysis indicated that participants increased the number of clicks and had shorter click intervals, before the time limit as the arousal condition became stricter. In contrast, participants had the shortest click interval times in TP after the time limit.

We developed a model diagrams representing behavioral characteristics before and after the time limit; Figures 7 and 8 respectively. In order to clearly show the differences in each arousal condition, these model diagrams demonstrate only the most difficult task, with a difficulty level of 15.

Figure 7 shows the most difficult task. It was nearly impossible for participants to complete the task within the time limit. Therefore, there are no differences in time between arousal conditions, as shown by the lengths of the three arrows represent elapsed time. However, as the arousal becomes more severe, participants clicked the mouse more often. The images of the hand over the mouse (hereinafter referred to as "mouse image") representing the number of clicks that participants clicked relatively few times in CT, but increased the number of clicks in TP and HA. This finding suggests that as the arousal level increases, individuals are more likely to perform any action, regardless of its appropriateness.

Similarly, participants click interval become shorter as the arousal condition became more severe. It can be seen from the diagram that the intervals of mouse images are narrower as the pressure increases from CT to TP and then to HA. This finding suggests that as the arousal level increases, individuals are more likely to think more shallowly and engage in impulsive behaviors. This tendency was also observed in our previous study (Ueda et al., 2013). Behavioral characteristics before the time limit in this study suggest that individuals are more likely to take temporary action without deep thinking.

Figure 8, also demonstrates the most difficult tasks. The length of the arrow representing elapsed time is the shortest in HA, identical to the results for necessary time. This shows that participants were capable of taking relatively prompt goal achievement behavior after the time limit, which is an emergency situation, only in difficult tasks.

On the other hand, behavior after the time limit indicated that participants had the shortest click intervals in TP. As can be seen in Figure 5, although the total number of clicks did not differ significantly, participants had the highest click rate in the TP condition under the highest level of difficulty, compared to the arousal condition. This suggests that if time pressure were the only stress after a time limit, individuals would spend less time thinking and would act more slowly than in emergencies, only when the task was difficult.

If a participant could not complete the task after 15 min (900 s), it was as a failure and forced the participant to discontinue the task. In fact, almost all dropouts were from the most difficult task, although the number of participants was different between the arousal conditions.

As can be seen from Figure 9, largest number of participants dropped out in TP, although the diffi-

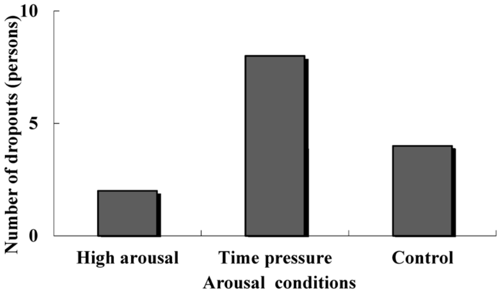

Figure 9 Number of task dropouts (persons) (Difficulty Level 15 only)

culty level was identical among the three conditions. We conducted a Cochran's Q test with the number of dropouts as a dependent variable and arousal conditions HA/TP/ and CT as independent variables, which results indicated a marginal difference in the main effect of arousal conditions ($Q(2)=4.667$, $p<.10$). A multiple comparison indicated that none of the results were significant, although the relationship between HA and TP was $p=.11$.

We could not conclude that there was a statistical difference between arousal conditions from the above results. However, the number of dropouts in TP indicates that 1 in 3.6 persons consequently discontinued the task, suggesting a high probability of dropping out, probably because participants no longer thought deeply when time pressure was the only factor being imposed after the time limit.

HA and TP had the identical time limit of 100 s, however, participants stopped thinking deeply in TP, but not in HA, because task seriousness was not included as a condition. Also, no damage would be caused even if participants discontinued the task. We can imagine this result by applying this finding to the expectancy-value theory, the famous model of achievement motivation (The expectancy-value theory is a general term for theories that define individual's behavior as a function of expectancies for goal achievement and values of the goal (incentive value; Akai, 1999). No certain results were to be expected in TP even if participants continued the task. If participants felt the task was too difficult for them, they could not find a subjective reason for continuing the task. Additionally, since the time limit was set in TP, which was unlike in CT, participants probably experienced a feeling of failure when they exceeded the time limit and the feeling of failure sharply decreased their achievement motivation. The classical study on level of aspiration conducted by Hoppe, also indicated that the level of aspiration decreases after a failure and could lead to the negation of a task (Seki, 1970).

In contrast, participants were able to take relatively prompt goal achievement behavior in HA after the time limit. They were capable of taking action after thinking. This behavior was presumably due to the consistent seriousness, which remained even after the time limit in HA. Since the time limit had passed, the effect of time urgency could have become weaker. However, the goal (seriousness) of maintaining the monetary reward remained among participants. Accordingly, participants maintained the motivation to continue with the task, even regardless of its difficulty. This psychological effect clearly attributes to the behavioral characteristic. This can be observed in the results of necessary time when the difficulty Level was 15. Participants had the shortest necessary time in HA because there was a clear seriousness, which was absent in TP and CT. This made prompt achievement behavior possible even after the time limit.

The Yerkes–Dodson law indicates that performance decreases in high arousal conditions. However, after the time limit in the present study, performance improved in the HA condition. This could be because the time urgency was reduced and the arousal level remained stable while motivation was maintained.

The generalization of the results of this study must be done carefully. In the present study, seriousness was defined as the reduction of monetary reward; however, it is possible that changing the context of seriousness would affect performance. For example, when a plant operator faces an emergency situation in real life that is similar to the simulation used in this study, the seriousness of the emergency would at first be related to how fast the operator is able to stop the water leak. After a certain time has passed, however, the context of seriousness would change to minimizing the damage caused by the leak. Seriousness in this real life example, and seriousness defined by reduced monetary reward in the present study are very different. Thus, in the future it would be important to define seriousness in different situations, and observe behavioral characteristics during emergencies, before and after the expiration of time limits.

Conclusion

Behavioral characteristics in emergencies before the time limit Individuals are likely to take temporary action, without deep thinking.

Behavioral characteristics in emergencies after time limit Individuals do prompt and thoughtful behavior, up to a certain level.

Individuals' behavior declines before the time limit in emergencies compared to normal. However, certain behaviors became positive after the time limit, suggesting that a clear goal (seriousness) should be maintained in emergencies, even after the time limit.

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