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A METHOD FOR CONTROLLING ARRIVAL TIME TO PREVENT LATE ARRIVAL BY MANIPULATING VEHICLE TIMETABLE INFORMATION

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Although it is socially and ethically important not to be late for a specified arrival time, late arrivals sometimes happen to people using public transportation. Although many methods aim to smooth a user's movement by providing useful information, there are few approaches to prevent late arrivals due to psychological factors. In this research, to make a user's arrival time earlier and thus prevent late arrival, we propose a method that manipulates time allowance by presenting information based on a psychological and cognitive tendency. We apply this method to a vehicle timetable system for the purpose of preventing public transit users from arriving after a target vehicle's departure time. Our proposed timetable system manipulates the time intervals between a user's target vehicle and other vehicles by introducing fictional elements such as hidden vehicles and inserted fictional vehicles. This method uses the relationship between the time allowance and the departure time interval, and it can make a user desire and accept arriving at a station earlier. We implemented a prototype system and conducted four experiments. The evaluation results confirmed that our proposed method is effective for changing a user's time allowance and actual arrival time.

Keywords: Information presentation, Psychological effect, Cognitive bias, Information manipulation, late arrival, self-control, Persuasive technology, Behavior change

1. Introduction

Although it is socially and ethically important not to be late for a specified arrival time, late arrivals sometimes happen. In fact, the results of a survey of 7,000 salaried workers revealed that 16% had been late at least once a week and that 27% had been late more than once a month [1]. In addition, in using public transportation, people often arrive later than the scheduled departure time of the vehicle that they had wanted to ride. In fact, the results of a survey of 3,413 people showed that 71% had missed their intended vehicles [2]. Such people who arrive late often lose social reliability and are punished in many scenarios and industries, because they are regarded as lazy and inconsiderate of others' time. In fact, the results of a survey of 3,000 employers revealed that 34% had fired employees because of late arrivals [1].

To prevent such late arrivals, many methods aim to smooth a person's movement by providing useful information. For example, various systems recommend a target vehicle for a destination and present the required transit time from a user's current position to a boarding station[3][4][5][6]. Such systems and applications have been developed by using network and computer technologies.

Although there is sufficient support to provide information that is convenient for a user's movement, there are few approaches to prevent late arrivals due to psychological factors, despite this being a common problem. Time allowance is also called as safety margin and a factor related to a person's arrival time. A time allowance consists of extra time that a person sets in advance so as to arrive on time, and the amount of extra time is affected by the person's psychological state [7][8]. On the other hand, although arriving earlier is a good way to prevent arriving late, it can also cause extra time between a person's self-arrival time and the departure time of the target vehicle to ride. Therefore, people often arrive late because of a lack of time allowance for various reasons, such as wanting to finish something before heading to a station or wanting to reduce the amount of waiting time at the station. Although it is also necessary to manipulate the time allowance for preventing late arrival, few such support approaches exist.

In this research, to enable earlier arrival times and prevent late arrival, we propose a method that manipulates the time allowance by presenting information based on a psychological and cognitive tendency. We apply this method to a vehicle timetable system for the purpose of preventing public transit users from arriving after a target vehicle's departure time. Our proposed timetable system manipulates the time intervals between the departures of the user's target vehicle and other vehicles by introducing fictional elements such as hidden vehicles and inserted fictional vehicles. This method uses the relationship between the time allowance and departure time intervals, and it makes users desire and accept arriving at a station earlier.

Our paper makes the following three contributions.

- To enable earlier arrival times and prevent late arrival, we proposed a method that manipulate time allowance by information presentation considering psychological tendency.
- We implemented prototype system by applying our method to a vehicle timetable system to prevent public transit users from arriving after a target vehicle's departure time.
- We conducted four experiments with total 98 subjects. Evaluation results confirmed that our proposed method is effective for changing a user's time allowance and actual arrival time, and it also confirmed relationship between vehicle timetable information and user's safety margin.

The remainder of this paper is organized as follows. Section 2 outlines related work. Section 3 describes the design of our system, and Section 4 explains the evaluation of our system. and Sections 5 presents our conclusion.

2. Related Work

To encourage a user to perform a target behavior, computer technologies for changing psychology and action have been proposed in such fields as health care, education, and tourism [9]. Various psychological factors have been used for this purpose. For example, one method uses competitive and cooperative spirits [10], while another uses a virtual pet that grows and develops depending on target behaviors performed by the user [11]. Another method uses morality by incorporating a rule to punish the user's partner as a result of the user's laziness in performing a target behavior [12]. Finally, another method uses the peer effect to enhance behavior among friends [13]. In addition, there are researches using information manipulation in order to effectively support user's behavior change. To improve speed of user's task execution, one method presents false elapsed time that is different from the actual one [14]. To improve user's food selection behavior and eating habit by using a system where a user's meal content is evaluated by other users on SNS(social networking service), another method positively modifies these evaluations so that the target user chooses a healthy meal [15]. To disperse crowd behavior and prevent crowd congestion in sightseeing scenes, another method presents recommendation that is modified for each user [16]. To enhance user's emotions and subsequent action, another method presents false facial expressions of themselves [17]. To manipulate user's satiety and food consumption, another method presents false apparent size of food [18]. Finally, to reduce user's stress in interpersonal communication and change communication, another method presents false size of others' appearance in terms of distance [19]. While information manipulation has the possibility of enabling not only good purpose but also evil purpose such as deception, correct use of it can effectively promote good purpose. These methods are examples that show the feasibility of our proposed method, which aims to change the user's actual behavior through a change in psychology.

Analysis and modeling of people in transit with a scheduled arrival time began in economics in the late 1960s [20]. Then, to estimate people's departure times and route selections, the theory was expanded to include analysis of cases with transit delays capable of occurring at only one location [21] or multiple locations [22], and analysis with consideration of differences among people [23]. Other analysis approaches target drivers [7] and commuters [8] and researched time allowance [7][8]. While these studies are only surveys, our research try to manipulate user's arrival times based on these researches.

Public transportation, which is a primary means of traffic movement, has increased its ridership in the U.S. in recent years because of a decrease in private vehicle use [25]. To help users avoid being late in using public transportation, many systems and applications have been proposed and become widespread. For example, one system recommends a target vehicle that is scheduled to arrive at the user's destination at a desired arrival time, while another system presents the required transit time from the user's current position to a boarding station, so that the user arrives at a target vehicle's departure time. Other such systems display a target vehicle's present location in real time [3], count down to a target vehicle's departure time [4], display an intuitive visualization of vehicle departure time intervals [5], and present information to support efficient shopping in station buildings [6]. While these previous systems aimed to solve problems caused by insufficiency of information that would be convenient for a user in transit, our proposed system aims to solve a problem caused by psychology by changing user's safety margin.

3. Proposed Method

Figure 1 shows an example of introducing a change in the time allowance with our method. To make the user's arrival time earlier and thus prevent late arrival, our method manipulates the time allowance by presenting information based on a psychological and cognitive tendency.

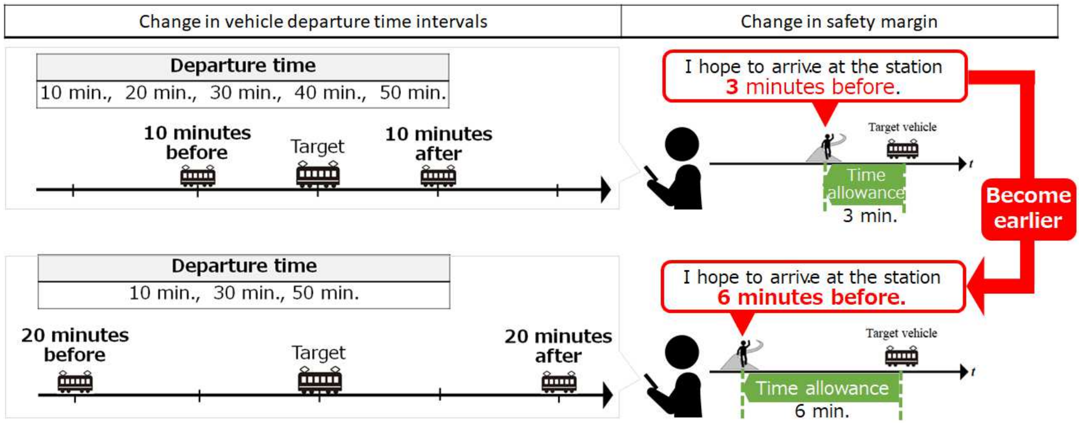


Fig. 1. Example of a time allowance change with our method.

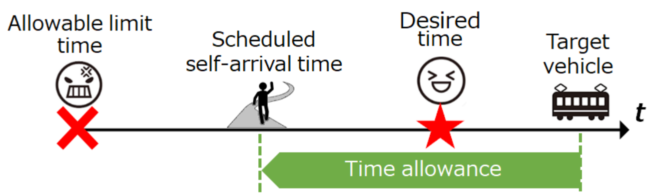


Fig. 2. Time allowance in our target scenario.

This method is applied to a public transit timetable system to prevent the user from arriving after a target vehicle's departure time. The proposed timetable system manipulates the departure time intervals between the user's target vehicle and other vehicles by hiding real vehicles and inserting fictional vehicles.

Target Scenario: The target scenario for our method is the case of a rider using public transportation such as a train or bus system. The user goes to a departure station so as not to miss a target vehicle. Here, the "target vehicle" is one that will arrive at the user's destination at the desired time.

Problem: In our target scenario, one factor in late arrival is a lack of time allowance. Here, "time allowance" is also called as safety margin and means extra time that people set aside in advance so as to arrive on time, and the amount of it is affected by a person's psychological state [7][8]. Although arriving earlier prevents late arrival, it also causes extra time between a person's self-arrival time and the target vehicle's departure time. Therefore, the self-arrival time can become later because of the lack of time allowance, for reasons such as delaying heading to a departure station when the user wants to finish something, when the current location is comfortable, or when the user wants to reduce the waiting time at the station.

3.0.1. *Manipulation of time allowance*

To manipulate the time allowance, our method adjusts both the user's desired time and allowable limit time for self-arrival at a boarding station.

Figure 2 illustrates the assumed time allowance in our target scenario. We define it as the

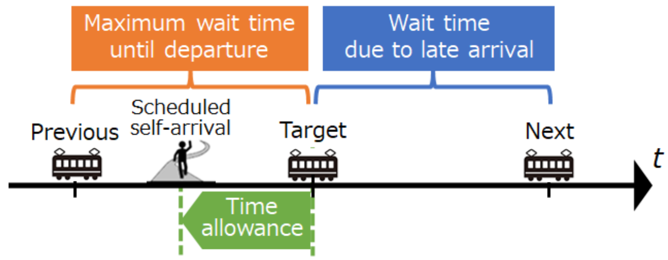


Fig. 3. Time intervals experienced as losses of time.

interval between the user's scheduled self-arrival time and the target vehicle's departure time. Here, the scheduled self-arrival time means the user's arrival time as imagined in advance. This scheduled self-arrival time is between the user's desired time of arrival at the station and allowable limit time for self-arrival, meaning a threshold time such that the user does not want to arrive any earlier.

We assume that the time allowance becomes bigger when the user's allowable limit time becomes even earlier than the desired time. In other words, our purpose requires making users desire and accept arriving earlier at the boarding station and waiting longer. To achieve this, we apply an approach of presenting information by using tendencies of a user's psychology and cognition. Such tendencies become a cause of cognitive bias, psychological effects, and illusions, which in turn cause subconscious changes in the user's psychology and cognition.

We assume that the time interval of vehicle departures subconsciously affects the time allowance. For example, the time interval affects the impression and feeling about a self-arrival time that is eight minutes before the target vehicle's departure time. Although this eight minutes seem near the allowable limit time with a 10-minute departure-time interval, it does not seem near the allowable limit time with a 30-minute departure-time interval. Such relative comparison is conducted when users do not have absolute self-standards about self-arrival time at a station. This is because people have no absolute self-criteria tend to unconsciously conduct relative comparison by using peripheral information [24].

Regarding the time interval for vehicle departures, we consider the following two types shown in Fig. 3.

1: Wait time due to late arrival

This time is the departure interval between the target vehicle and the next vehicle. It is thus the cost incurred by arriving too late for the departure time of the target vehicle. Previous research also assumed that a penalty for late arrival affects the time allowance in analysis of movement under temporal restrictions for delivery truck drivers and commuters [7][8].

2: Maximum wait time until departure

This time is the departure interval between the target vehicle and the previous vehicle. It is thus the maximum wait time from the self-arrival time at the station until the target vehicle's departure. We assume that this time affects the user's self-arrival time.

As for the relationship with the time allowance, we assume that it increases to some extent in proportion to the above two types of time intervals. For example, self-arrival time that is four minutes before the target vehicle's departure time seems late when wait time due to late arrival is 20 minutes compared with the wait time is 10 minutes. Self-arrival time that is eight minutes before the target vehicle's departure time seems early when maximum wait time until departure is 10 minutes compared with the maximum wait time is 20 minutes.

From the above assumption, our method aims to enlarge the time allowance by manipulating the time interval between vehicle departures in a timetable.

Our method has two types of manipulations. The first type is a vehicle hiding method, which hides specific vehicles and widens the time interval between departures at specific time-axis locations. In the basic setting, to widen the time interval to twice the original interval, vehicles other than the target vehicle are thinned out at an interval of one vehicle. The second type of manipulation is a fictional-vehicle insertion method, which inserts fictional vehicles and thus narrows the time interval between departures at specific time-axis locations. Because an appropriate rule for changing the time allowance by such vehicle insertion is unknown, we investigated this issue in the experiments described in section 4.

For two reasons, our method uses both a vehicle timetable and fictional information. First, the timetable enables a user to browse information provided by our method without any unexpected steps in the target scenario, because a timetable generally has time intervals for departures and is used in public transportation. Second, we use fictional elements because of research on the effects of similar methods that encourage a desired behavior from the viewpoint of time by mixing fictional elements into time information browsed by a user. For example, one method accelerates the speed of a clock to encourage execution of a task within a limited amount of time [14]. In another general method, which is not based on research but commonly used, a person sets a clock's time ahead by a few minutes to encourage faster action. These examples show the effectiveness of adjusting a user's behavior from the viewpoint of time by changing the environment of time information, which supports the feasibility of our method.

3.1. *Prototype system*

Using our proposed method, a prototype vehicle timetable system recommends a target vehicle and shows a vehicle timetable. The target vehicle is one that arrives at the destination station at the user's desired time.

Target vehicle selection works the same as in general vehicle timetable system. First, the user inputs a departure station or location, a destination station or location, and the desired arrival time. When locations (i.e., not stations) are inputted, the system selects a departure station and a destination station according to the latitudes and longitudes of the input locations. Then, it calculates the time when the user should arrive at the destination station according to the route and walking time from the destination station to the destination location. Finally, the system selects a target vehicle. The target vehicle is the last vehicle that will arrive at the destination station by the time when the user should arrive at the station. To facilitate this approach, the system presents a timetable that includes both correct vehicle timetable information and fictional elements for manipulating the time intervals of vehicle departures.

Figure 4 shows the application screen of our implemented prototype system. The application was implemented by using HTML and JavaScript and vehicle timetable information.

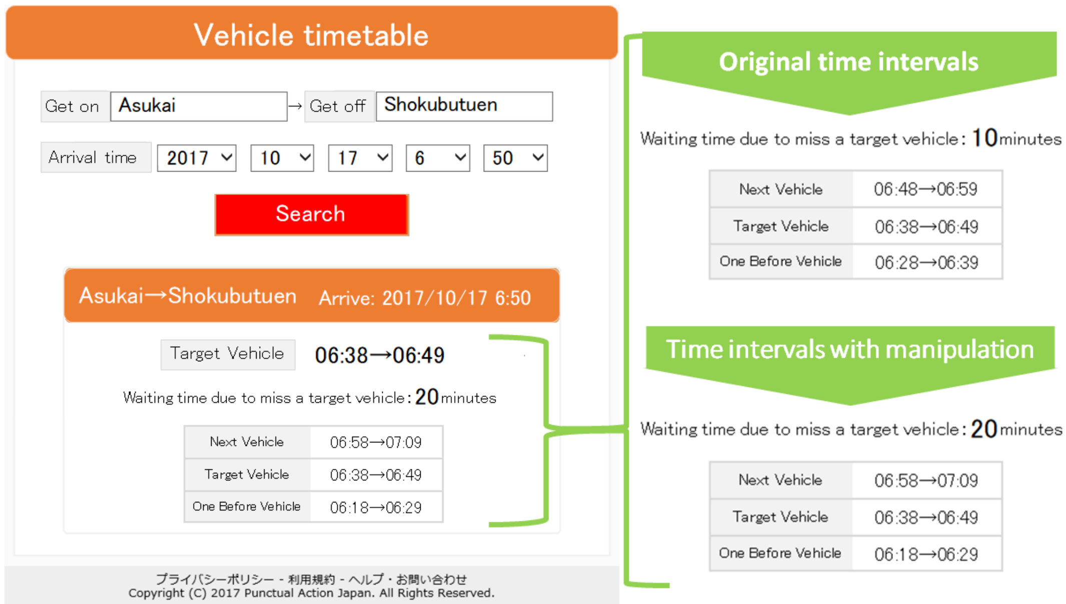


Fig. 4. Screen of our prototype system

The Google Maps API [26] is used to calculate a route and the route distance between two points. The HeartRails Express service is used to find the nearest station from a designated location. The upper part of the screen is an input area for vehicle search conditions such as the desired time to arrive at a destination. The lower part is an output area for vehicle information such as a target vehicle to ride and the waiting time if the user misses it.

The right part of Fig. 4 also shows an example of the difference in presented information between the standard approach and our proposed method. The standard approach displays all vehicles, while the proposed method thins out those vehicles to change the possible waiting time due to the user's late arrival.

4. Evaluation

We evaluated the effectiveness of our method through multiple experiments. Experiment 1 evaluated whether our method could change the time allowance and surveyed the resulting characteristics of these changes. It consisted of three individual experiments using two variations of our method. Then, Experiment 2 evaluated whether our method could change a user's actual arrival time. This experiment was conducted with permission of the ethical review committee member of our university.

4.1. *Experiment 1-1: Vehicle hiding method*

This experiment evaluated whether our method could change the time allowance by using the vehicle hiding method. It consisted of 41 subjects, with 32 men and nine women. Their average age was 22 years, with a standard error of 0.3.

Tasks: The experimental task was to set the time allowance under different experimental

Table 1. User questions on self-arrival.

Q1	Desired self-arrival time: The time when the subject wanted to arrive at a departure station to ride a target vehicle. This answer was expressed in terms of the number of minutes before the target vehicle's departure time. For example, an answer of "4 minutes" meant that the subject wanted to arrive at the station 4 minutes before departure.
Q2	Allowable limit for self-arrival time: The time threshold for which the subject did not want to arrive at the departure station any earlier. This answer was expressed in the same way as for Q1. For example, an answer of "8 minutes" meant that the subject could not accept arriving at the station earlier than 8 minutes before departure.

conditions presenting different information about time intervals. First, the subjects imagined their actual destinations and desired times when they wanted to arrive there. After conducting the procedure with actual usage of the prototype system, the subjects browsed the presented vehicle timetable and answered questions related to the time allowance. As suggested above, this task was conducted under multiple experimental conditions that presented different time intervals for vehicle departures. The subjects were given an explanation in advance about the meaning of the information presented by the system.

Questions: Table 1 lists the questions answered by the subjects. Q1 asked for the desired self-arrival time, meaning the time when the subject wanted to arrive at a station to catch a target vehicle. Q2 asked for the allowable limit for the self-arrival time, meaning the time threshold for which the subject did not want to arrive at the station any earlier. The subjects answered these questions in terms of how many minutes they would arrive before the target vehicle's departure time. Illustration is shown in Figure 2 that is mentioned in section 3.

Experimental conditions: Regarding time interval condition, we used four different time intervals of 5, 10, 20, and 30 minutes. Subject answered these conditions for the two different vehicle types of bus and train to investigate the time allowance characteristics.

4.2. *Results*

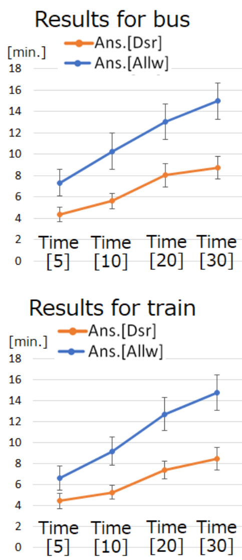
We performed two-way analysis of variations (ANOVA) and multiple comparison tests on the results, as listed in Table 2. The factors in the two-way ANOVA were the time interval condition and question responses (i.e., the desired self-arrival time or allowable limit), expressed as "Time" and "Ans.", respectively, in the table. Time[5], Time[10], Time[20], and Time[30] express departure time intervals of 5, 10, 20, and 30 minutes, respectively. Finally, Ans.[Dsr] and Ans.[Allw] express the desired self-arrival time and allowable limit, respectively. $**$ means $p < 0.01$, $*$ means $p < 0.05$, and $n.s$ means no significant difference.

Figure 5 shows the average results for all subjects and multiple comparison tests. The error bars indicate the standard errors. The horizontal axis indicates the departure time interval, while the vertical axis indicates the subject's response in minutes before the departure time of a target vehicle. For example, a plot of 8 minutes means that subject's arrival time is 8 minutes before a departure time of a target vehicle.

These results supported our hypothesis by showing that the desired self-arrival time and the allowable limit became earlier with enlarged vehicle departure time intervals. This tendency was the same for both trains and buses. Specifically, between the time intervals of 5 and 30 minutes, the desired self-arrival time became about 4 minutes earlier, while the allowable limit time became about 7.5 minutes earlier. The degree of change of the allowable limit was

Table 2. Statistical test result in experiment 1-1.

Analysis of Variance								Analysis of Ans.×Time Interaction						
	Bus			Train					Bus			Train		
S.V	df	F	p	df	F	p		S.V	df	F	p	df	F	p
Ans.	1	21.4	**	1	18.0	**		Ans. at Time[5]	1	11.5	**	1	5.9	**
Time	3	43.4	**	3	46.0	**		Ans. at Time[10]	1	13.2	**	1	17.4	**
Ans. × Time	3	9.1	**	3	16.7	**		Ans. at Time[20]	1	17.9	**	1	19.8	**
								Ans. at Time[30]	1	40.9	**	1	21.9	**
								Time at Ans.[Dsr]	3	26.0	**	3	24.4	**
								Time at Ans.[Allw]	3	40.8	**	3	46.9	**



Multiple Comparisons by Bonferroni (∗ p<0.05)		
	Time at Ans.[Dsr]	Time at Ans.[Allw]
Time[5] × Time[10]	(n.s)	<(∗)
Time[5] × Time[20]	<(∗)	<(∗)
Time[5] × Time[30]	<(∗)	<(∗)
Time[10] × Time[20]	<(∗)	<(∗)
Time[10] × Time[30]	<(∗)	<(∗)
Time[20] × Time[30]	(n.s)	(n.s)

Multiple Comparisons by Bonferroni (∗ p<0.05)		
	Time at Ans.[Dsr]	Time at Ans.[Allw]
Time[5] × Time[10]	(n.s)	<(∗)
Time[5] × Time[20]	<(∗)	<(∗)
Time[5] × Time[30]	<(∗)	<(∗)
Time[10] × Time[20]	<(∗)	<(∗)
Time[10] × Time[30]	<(∗)	<(∗)
Time[20] × Time[30]	(n.s)	<(∗)

Fig. 5. Result of multiple comparisons test in experiment 1-1

bigger than that of the desired time. In addition, the time allowance seemed not to become bigger beyond a certain level, because it showed no significant difference between time intervals of 20 and 30 minutes. These results show that subjects came to desire and accept that they should arrive at the departure station earlier according to the presented information.

4.3. *Experiment 1-2: Additional experiment*

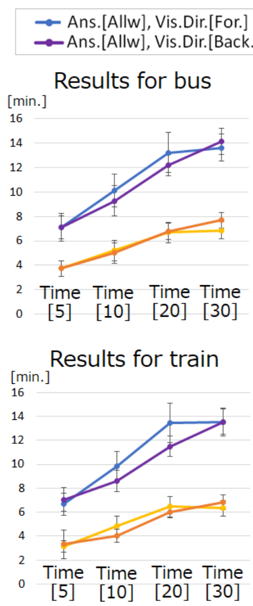
In experiment 1-1, the effect of our method was evaluated under conditions that showed both the previous and subsequent vehicles from the target vehicle, so the effect for each direction was unclear. Therefore, this experiment evaluated the effect of our method separately for each visible direction. The experiment was performed by 22 subjects, with 18 men and 4 women. Their average age was 23 years, with a standard error of 0.2.

In this experiment, the subjects consciously set the time allowance for each information type, under different experimental conditions as in the previous experiment. We thus added visible direction condition that consisting of either vehicles departing before the target vehicle or vehicles departing after the target vehicle.

We performed three-way ANOVA and multiple comparison tests for these results, as listed

Table 3. Statistical test result in experiment 1-2

Analysis of Variance								Analysis of Ans.×Time Interaction						
	Bus			Train					Bus			Train		
S.V	df	F	p	df	F	p		S.V	df	F	p	df	F	p
Vis. dir.	1	0.0	$n.s$	1	1.2	$n.s$		Ans. at Time[5]	1	55.9	$**$	1	63.3	$**$
Ans.	1	91.4	$**$	1	96.1	$**$		Ans. at Time[10]	1	78.6	$**$	1	94.2	$**$
Time	3	31.2	$**$	3	31.3	$**$		Ans. at Time[20]	1	66.4	$**$	1	65.8	$**$
Vis. dir. × Ans.	1	0.1	$n.s$	1	1.3	$n.s$		Ans. at Time[30]	1	76.6	$**$	1	76.8	$**$
Ans. ×Time	3	14.9	$**$	3	14.5	$**$		Time at Ans.[Dsr]	3	26.0	$**$	3	24.4	$**$
Vis. dir. ×Time	3	1.3	$n.s$	3	2.6	$n.s$		Time at Ans.[Dsr]	3	20.6	$**$	3	22.0	$**$
Vis. dir.× Ans. ×Time	3	0.6	$n.s$	3	1.7	$**$		Time at Ans.[Allw]	3	31.8	$**$	3	30.5	$**$



Multiple Comparisons by Bonferroni ($*$ p<0.05) — bus

	Time at Ans.[Dsr]	Time at Ans.[Allw]
Time[5] × Time[10]	<($*$)	<($*$)
Time[5] × Time[20]	<($*$)	<($*$)
Time[5] × Time[30]	<($*$)	<($*$)
Time[10] × Time[20]	<($*$)	<($*$)
Time[10] × Time[30]	<($*$)	<($*$)
Time[20] × Time[30]	(n.s)	(n.s)

Multiple Comparisons by Bonferroni ($*$ p<0.05) — train

	Time at Ans.[Dsr]	Time at Ans.[Allw]
Time[5] × Time[10]	(n.s)	<($*$)
Time[5] × Time[20]	<($*$)	<($*$)
Time[5] × Time[30]	<($*$)	<($*$)
Time[10] × Time[20]	<($*$)	<($*$)
Time[10] × Time[30]	<($*$)	<($*$)
Time[20] × Time[30]	(n.s)	(n.s)

Fig. 6. Result of multiple comparisons test in experiment 1-2

in Table 3. The factors in the three-way ANOVA were the visible direction condition, the time interval condition, and the question responses, expressed by “Vis. dir.”, “Time”, and “Ans.”, respectively, in the table. Vis.dir.[For.] and Vis.dir.[Back.] express visible direction consisting of whether vehicles departing before the target vehicle or vehicles departing after the target vehicle. Time[5], Time[10], Time[20], Time[30], Ans.[Dsr], and Ans.[Allw] express the same quantities as in the results of experiment 1-1. Figure 6 shows the average results for all subjects and multiple comparison tests. The error bars and the horizontal and vertical axes are the same as in Fig. 5 in the experiment 1-1. $**$ means $p < 0.01$, $*$ means $p < 0.05$, and $n.s$ means no significant difference.

These results showed no significant difference between the visible directions, and this tendency was the same for both trains and buses. We thus found that visibility of vehicles departing before and after the target vehicle have similar effects on the user’s time allowance.

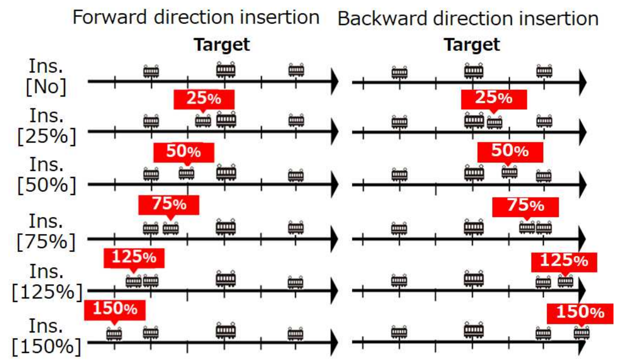


Fig. 7. Insertion position of a vehicle insertion condition

Table 4. Statistical test result in experiment 1-3 for 10 minutes interval

Analysis of Variance								Analysis of Ans.× Ins. Interaction						
	Bus			Train					Bus			Train		
S.V	df	F	p	df	F	p		S.V	df	F	p	df	F	p
Ins. Dir.	1	1.9	$n.s$	1	3.9	0.1		Ans. at Ins.[No]	1	91.5	**	1	70.9	**
Ans.	1	94.9	**	1	84.1	**		Ans. at Ins.[25%]	1	69.0	**	1	68.3	**
Ins.	5	11.3	**	5	10.2	**		Ans. at Ins.[50%]	1	62.8	**	1	67.0	**
Ins. Dir. × Ans.	1	1.8	$n.s$	1	2.7	$n.s$		Ans. at Ins.[75%]	1	72.7	**	1	67.4	**
Ans. × Ins.	5	3.5	**	5	2.5	*		Ans. at Ins.[125%]	1	95.6	**	1	87.7	**
Ins. Dir. × Ins.	5	1.8	$n.s$	5	2.8	*		Ans. at Ins.[150%]	1	75.8	**	1	78.7	**
Ins. Dir.× Ans. × Ins.	5	2.1	$n.s$	5	0.5	$n.s$		Ins. at Ans.[Dsr]	5	8.4	**	5	8.0	**
								Ins. at Ans.[Allw]	5	11.0	**	5	10.1	**

4.4. *Experiment 1-3: Vehicle insertion method*

Whereas experiments 1-1 and 1-2 used our vehicle hiding method, this experiment used our vehicle insertion method and evaluated whether it changed the time allowance. This experiment had 23 subjects, with 19 men and 4 women. Their average age was 23 years, with a standard error of 0.2.

The subjects consciously set the time allowance for each type of information under different experimental conditions, as in the previous experiments. The experimental conditions were as follows. Regarding the insertion position conditions for fictional vehicles, Figure 7 illustrates the various insertion positions. They were inserted at six different positions with respect to the original departure interval from the target vehicle at the interval of 25% of the original departure interval: no insertion, 25%, 50%, 75%, 125%, and 150%. For example, if the original departure interval was 10 minutes and the insertion position was 25%, then the position of the inserted vehicle was shifted by approximately two and a half minutes. In addition, there were two insertion direction conditions. In the first condition, a fictional vehicle was inserted before the target vehicle's departure. In the other condition, a fictional vehicle was inserted after the target vehicle's departure. Both directions from the target vehicle were visible to the subjects in this experiment. The experiment was conducted separately for the two vehicle types of bus and train and two original departure times of 10 and 20 minutes.

4.5. *Results*

We performed three-way analysis of variations (ANOVA) and multiple comparison tests on

Table 5. Statistical test result in experiment 1-3 for 20 minutes interval

Analysis of Variance								Analysis of Ans.× Ins. Interaction						
	Bus			Train					Bus			Train		
S.V	df	F	p	df	F	p		S.V	df	F	p	df	F	p
Ins. Dir.	1	2.0	$n.s$	1	3.1	$n.s$		Ans. at Ins.[no]	1	113.1	$**$	1	96.9	$**$
Ans.	1	114.7	$**$	1	85.6	$**$		Ans. at Ins.[25%]	1	101.5	$**$	1	80.3	$**$
Ins.	5	8.4	$**$	5	7.4	$**$		Ans. at Ins.[50%]	1	136.8	$**$	1	114.6	$**$
Ins. Dir. × Ans.	1	0.7	$n.s$	1	0.4	$n.s$		Ans. at Ins.[75%]	1	147.9	$**$	1	107.3	$**$
Ans. × Ins.	5	4.6	$**$	5	3.0	$*$		Ans. at Ins.[125%]	1	64.3	$**$	1	52.2	$**$
Ins. Dir. × Ins.	5	1.0	$n.s$	5	1.6	$n.s$		Ans. at Ins.[150%]	1	57.0	$**$	1	42.6	$**$
Ins. Dir.× Ans. × Ins.	5	2.2	$n.s$	5	1.3	$n.s$		Ins. at Ans.[Dsr]	5	4.6	$**$	5	4.8	$**$
								Ins. at Ans.[Allw]	5	9.3	$**$	5	6.7	$**$

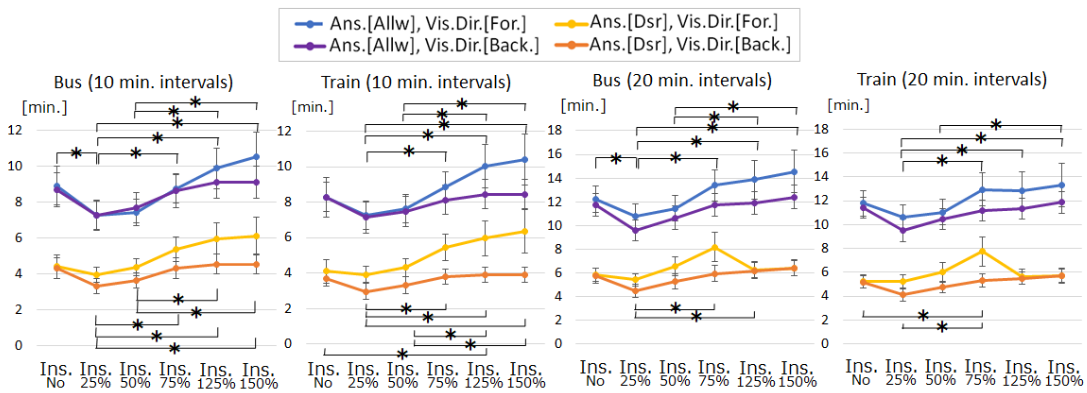


Fig. 8. Result of multiple comparisons test in experiment 1-3

the results, as listed in Table 4 and 5. The factors in the three-way ANOVA were the insertion direction condition, the insertion position condition, and the question responses, expressed by “Ins. dir.”, “Ins.”, and “Ans.”, respectively, in the table. Ins. dir.(Pre.) and Ins. dir.(Sub.) express whether fictional vehicle was inserted before the target vehicle's departure. Ins.[No], Ins.[25%], Ins.[50%], Ins.[75%], Ins.[125%], and Ins.[150%] express insertion position conditions. Ans.[Dsr] and Ans.[Allw] express the desired self-arrival time and allowable limit, respectively. $**$ means $p < 0.01$, $*$ means $p < 0.05$, and $n.s$ means no significant difference. Figure 8 shows the average results for all subjects and multiple comparison tests. The error bars indicate the standard errors. The horizontal axis indicates where to insert fictional vehicle, while the vertical axis indicates the subject's response in minutes before the departure time of a target vehicle.

In the results, subjects' answer about safety margin changed depending on the insertion position. Compared to the no insertion condition, inserting vehicle around 25% made the results in the direction of making their arrival time late. Such insertion has a possibility of leading to user's late arrival. In addition, compared to the no insertion condition, inserting vehicle after 75% made the results in the direction of making their arrival time earlier. Such insertion has a possibility of preventing user's late arrival. There were similar tendencies despite original departure time intervals of 10 minutes and 20 minutes and vehicle types of bus and train. Although there is no significant difference between the insertion direction condition, this tendency seems stronger in condition of inserting fictional vehicle before the target vehicle's departure. We consider that it is easier to be aware of the fictional vehicle that is inserted before target vehicle. From the above, we confirmed changes in safety margin due to vehicle insertion.

4.6. *Experiment 2: Actual self-arrival*

Next, Experiment 2 evaluated the effect of our proposed method on the actual self-arrival time through behavior changes in a practical experiment. The subjects were 12 people, with 10 men and 2 women, and their average age was 22.3 years.

This task was designed to evaluate a subject's actual arrival time with respect to the target vehicle's departure time. We selected a bus as a vehicle for this experiment. In the task, the subjects went to their destination by using our system, with the actual vehicle ride is replaced by photography. Specifically, the subjects had to arrive at a departure station before the target vehicle's departure time and then photograph the target vehicle. When the subjects were late for the target vehicle's departure time, they had to wait at the departure station until the next vehicle's departure time and then photograph that vehicle. Therefore, they could arrive at their destinations at the desired arrival times when they were in time for their target vehicles' departure times. The subjects performed this task once a day under two different experimental conditions. Because these conditions had different time intervals for vehicle departures, the subjects' waiting times when they were late for their target vehicles differed between the two conditions.

Experimental conditions: The time interval for vehicle departure was 10 minutes under condition 1 and 20 minutes under condition 2. Thus, the waiting time at a boarding station because of late arrival was 10 or 20 minutes under condition 1 or condition 2, respectively. Condition 2 used the proposed method mixing fictional time intervals into the vehicle departures under condition 1. We thus selected boarding stations that has vehicle timetable with a 10-minute time interval for vehicle departures.

The procedure of experiment 2 was as follows. The subjects agreed to participate on the day before the experiment day. We explained the experimental task and the meaning of information presented by our system.

The experiment consisted of three stages of browsing, movement, and arriving. The first was the browsing stage. On the day of the experiment, a subject's location was either a university or home. The subjects inputted their destinations and times when they wanted to arrive there. Then, they checked the presented information showing the target vehicle's departure time, the departure station, and the waiting time if they were late for the departure time. This stage was conducted two hours or more before the subjects headed to their destinations. In this stage, the time intervals for vehicle departure differed among the experimental conditions.

The second stage was the movement stage, in which the subjects headed toward a designated bus station at their own timing. The assigned boarding station was located 10-15 minutes on foot from the subject's location.

The third stage was the arriving stage, in which the subjects performed two actions. First, they took photographs of the assigned boarding station when they arrived there, to provide evidence of their arrival times. Second, they waited until the target vehicle arrived and then photographed it, to provide evidence of the target vehicle without actually riding it. The

Table 6. Results of experiment 2 for each subject, listed as arrival times.

	Condition 1 (10-minute interval)	Condition 2 (20-minute interval)	Deference between conditions
Sub.1	6	-9	-15
Sub.2	5	-6	-11
Sub.3	0	-6	-6
Sub.4	-3	-7	-4
Sub.5	-5	-7	-2
Sub.6	-2	-4	-2
Sub.7	-9	-10	-1
Sub.8	-2	-3	-1
Sub.9	-2	-2	0
Sub.10	-1	-1	0
Sub.11	-2	-1	1
Sub.12	-5	-3	2

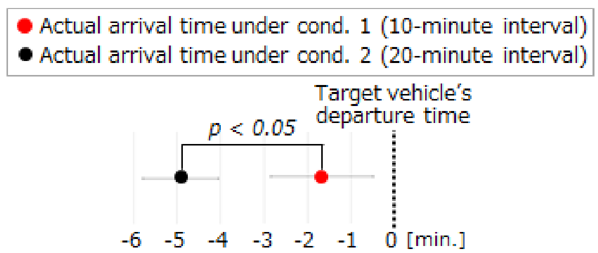


Fig. 9. Average arrival time values for all subjects in experiment 2.

experiment ended for a subject when the target vehicle was photographed. When a target vehicle did not arrive within 5 minutes after its scheduled departure time, the subject was allowed to end the experiment without photographing the target vehicle. If a subject was late for a target vehicle's departure time, he or she had to wait until the next vehicle arrived and then photograph it. Each subject performed this task twice, under each of the two conditions, with a random execution order.

4.7. *Results*

Table 6 lists the subjects' arrival times under each condition, and Figure 9 shows the average values under each condition for all subject. The number of minutes is expressed based on the target vehicle's arrival time. For example, subject 1 arrived 6 minutes after the target vehicle's departure time under condition 1, but 9 minutes before the departure time under condition 2. The rightmost column represents the change in arrival time under condition 2 as compared with that under condition 1. The error bars indicate the standard error. The result of a t-test showed that the subject arrival times were significantly different between the two conditions [$p < 0.05$]. Specifically, the average arrival time under condition 2 was about 2.9 times earlier than that under condition 1.

The results showed that our proposed method could change a subject's actual arrival time and behavior. We consider the actual arrival time to have been affected by the change in the time allowance. Hence, these results confirm that our proposed method is effective for preventing a user from arriving late for a target vehicle's departure time.

The results for each subject indicated individual differences regarding the tendency and degree of effect of the presented information. There were two main tendencies. The first was the expected tendency, in which the arrival time was earlier under condition 2 than under condition 1. This tendency occurred for eight subjects (i.e., about 67% of the subjects). The second tendency indicated no effect and occurred for four subjects, whose arrival time under condition 2 was not significantly earlier than that under condition 1. For example, subjects 11 and 12 showed this tendency. It would be desirable to know the self-effect tendency in using our system, so we plan to apply an inspection method to understand individual effects beforehand, such as a simple questionnaire.

4.8. *Discussion*

Our experimental results indicated that manipulation of time intervals in a timetable is effective for encouraging a desired behavior from the viewpoint of time. We considered that this indication is important for system design to support people using information on time intervals. In addition, we considered that our proposed method can be applied in various scenarios involving an event's time interval. One such scenario is preventing a rider from arriving late in using public transportation. In addition, our method could be used to prevent congestion through reduction of traffic and train occupancy rates by manipulating the arrival times of many people. We thus plan to examine such possibilities in other target scenarios.

The results also indicated that presenting a vehicle timetable without any consideration may introduce unintended effects. One example of an unintended effect would be a user's late arrival for a target vehicle's departure time. We consider that such information about time intervals should be designed in consideration of this viewpoint of a user's psychology.

Our system design was based on the premise that the user's main purpose for this system would be to catch a target vehicle rather than to see an accurate vehicle timetable. To achieve this main purpose, we introduced information manipulation. We consider that such design will be important in various scenarios other than our target scenario as opportunities to present information increase. We also consider that information manipulation of our method has no ethical problem because technology is neither good nor bad [27] and our method is not deception that is evil use of information manipulation to lead people in a bad direction by cheating [28].

Regarding the disadvantage of using fictional elements in a timetable, this approach may cause unnecessary problems. For example, fictional elements might hurry users who would otherwise be on time for a target vehicle without being in hurry, or they may cause problems such as users ignoring traffic rules and experiencing collisions with people and cars. Because such problems can occur with both real and fictional information, it is necessary to devise a mechanism that can use only the good characteristics of each kind of information.

We did not evaluate the effect of our method for users who understand that the timetable contains fictional elements. We hypothesize that the effect would be similar to that of the experiments reported in this paper, because users would have no choice but to believe in the information, unless they knew exactly what information was fictional. In addition, we assumes that users will understand our method and consciously choose to apply it, as in the case of setting a clock forward themselves.

5. Conclusion

In this research, to enable earlier arrival times and prevent late arrival, we proposed a method that manipulates the time allowance about self-arrival time by presenting information based on a psychological and cognitive tendency. Our proposed method on vehicle timetable system manipulated vehicle departure time intervals by introducing fictional elements such as hidden vehicles and inserted fictional vehicles. This method used the relationship between the time allowance and vehicle departure time intervals. We implemented a prototype system and conducted four experiments. The evaluation results confirmed that our proposed method is effective for changing a user's time allowance and actual arrival time. Experimental results also showed future work. We plan to long-term evaluation and construct an pre-inspection method to deal with individual tendency of effects by our method, such as a simple questionnaire.

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