Human Factors in Transportation, Vol. 95, 2023, 154–160
https://doi.org/10.54941/ahfe1003801

Development of Scenario-Based Approach Aided by Key PSFs to Design of New Interface of Autonomous Vehicles Monitoring System: A Case Study

Hirotaka Aoki[1], Nozomi Kobayashi[1], Mizuki Fuke[1], and Tomonori Yasui[2]

[1]Tokyo Institute of Technology, Tokyo, Japan
[2]Mitsubishi Electronic Corporation, Hyogo, Japan

ABSTRACT

This paper develops an interface design methodology in which the scenario-based design aided by predetermined performance shaping factors. The methodology is developed to enables us to create the scenarios, which is the key success components in the designing processes, efficiently and effectively by showing context factors shaping human behavior/performance. We performed a case study where the developed methodology was applied to design a future user-centered interface of autonomous vehicle monitoring and controlling systems. Based on the results and implications obtained from the application, the potential uses of our methodology are discussed.

Keywords: Human-centred design technique, Autonomous vehicles, Improved scenario-based design, Interface design

INTRODUCTION

In the present paper, we develop an improved scenario-based design approach to design a new interface of the monitoring system for autonomous vehicles that adapts to the autonomous driving levels 4 to 5 condition. Although the future society with high-level autonomous vehicles such as those having levels 4 to 5 is clearly anticipated, there still remains much uncertainty relating to how autonomous vehicles are implemented in terms of platform technology (e.g., AI, image processing, etc.), social norms (e.g., laws, safety responsibility, etc.), context of use (e.g., human role, allocated tasks, etc.) and so forth. For example, it is unclear the followings: What can be done automatically by the platform technologies of autonomous vehicles (i.e., uncertainty in technological advancement), what kind of socio-technical support can be given when human operators have to intervene in a critical incident that cannot be managed automatically (i.e., uncertainty in tasks required to human), etc. Caused by these uncertainties, it is of great difficulty to design user-centered interface of autonomous vehicle control/monitoring systems since the users/operators' tasks and needs are not well defined.

The paper proposes a design approach adapting to the above-mentioned background issues. The most part of the approach is based on scenario-based design (Rosson and Carroll 2002). This is referred to as the technique to elicit effective specifications of interface based on scenarios in which how a human uses and interacts with a specific system are vividly described to capture the essence of interaction and physical design. In the approach, requirements/rough draft of basic specifications are elicited by interpreting desirable interaction/behavior described in the scenarios Although the scenario-based design is applicable for a new product design, creating successful scenario having appropriate level of details and in which key behaviors/tasks and their contexts are covered requires rich knowledge about interaction design as well as expertise/experiences in practice. In order to support the difficulty in creating scenarios, we propose a series of processes where scenarios are created and refined iteratively supported by a list of PSFs (performance shaping factors) directly connected with the system's context of use. The list of PSFs are, in our processes, used as guidelines/heuristics not only to obtain insight for creating narrative description of a human, but also to keep consistency of envisioned usage episodes in scenarios (refined iteratively) by maintaining an orientation to identical key context factors.

DEVELOPMENT PROCEDURE PROPOSED

Scenario-Based Design Approach

As mentioned before, our systems design approach is developed for designing of HMI of autonomous vehicles monitoring systems. Since this is a new system development project, competing products analysis cannot be conducted. In this context, it can be expected that Scenario-based design (Rosson et al. 2001, Rosson et al. 2002) gives a great insight about determination of systems specifications. The overall image of the design process is depicted in Figure 1. Scenario in this scenario-based design is a narrative description where the user of a future system/product is concretely and vividly described. Various versions of scenarios are used at an early point in the early stage of the development processes in order to determine specifications. Since the scenarios involves narrative descriptions of envisioned usage episodes, they enable design teams to focus not on technical aspects but on user experiences. By taking a top-down thinking process in which the user's behaviors in the scenarios are deployed to the system's/product's functionality to be implemented, preliminary users' requirements and specifications can be elicited.

Though the scenario-based design seems promising, the success of the design is heavily depending on the quality of scenarios. A scenario which is really effective for design should have stories telling how users will use the system/product to accomplish tasks and relating other activities vividly including critical contexts which are the essences of interactions. The creation of such effective scenarios requires both of rich expertise in theories (e.g., psychological theories relating to interaction designs) and good senses in writing. Considering the above-mentioned requirements, some supporting

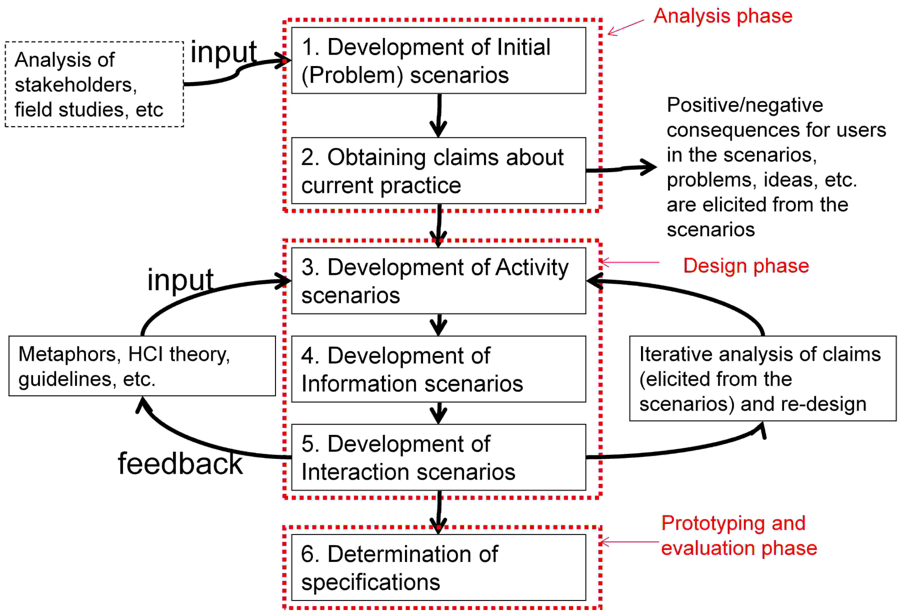

Figure 1: Scenario-based design processes.

tool to create scenario is strongly required, especially from practical point of view.

Scenario Creation and Refinement Aided by PSFs List

To support creation of effective scenario, we think that a predetermined list of items that should be described in scenarios is one possible tool. In the field of HRA (Human Reliability Analysis), performance shaping factors (PSFs) are considered to examine human error rates in various HRA methodologies (e.g., Lee et al. 2011). PSFs are referred to as the factors affecting human behaviour. For example, THERP (Technique for Human Error Rate Prediction), which is one of the most famous and traditional HRA methodologies, provides the PSFs in a nuclear power plant domain (Kirwan 1996, Kirwan et al. 1997). The PSFs in THERP system can apply for other domains which include human monitoring tasks. The PSFs in THERP system is consisted of the following three categories: External PSFs, stressor PSFs and internal PSFs (in detail, see Kirwan 1994). These PSFs are well-organized, and can be used as predetermined items that should be considered when creating a scenario.

Figure 2 shows a summary of scenario creation procedure. For example, the PSFs in THERP included in external PSFs are classified into three sub categories. The first category named “situational characteristics” has nine items in total. Following the procedure shown in Figure 2, we examine whether the item is closely connected with the user’s behavior in the specific product. If the item has to be considered, we create a description (e.g., brief episode of usage), and keep the item in the revised list. In the end of the procedure, we can obtain descriptions as well as the items that are likely to be critical for the context of use. By synthesizing descriptions, a story representing how a user behaves is created.

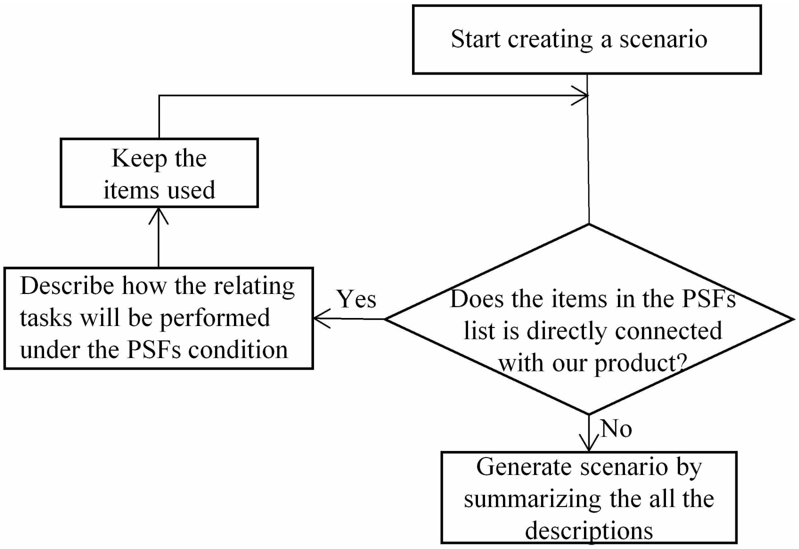

Figure 2: Scenario creation processes.

CASE STUDY: DESIGN OF NEW INTERFACE OF AUTONOMOUS VEHICLES MONITORING SYSTEM

Creation of Scenario Aided by PSFs

The present study is a collaborative work with a Japanese manufacturing company. The company started a project where it develops a HMI of autonomous vehicles monitoring system. This is the first experience for the company to develop such system, since the level of autonomous vehicles in Japan is not so high meaning that this kind of system is recognized as future products. To check the feasibility of our development procedure, we apply it to the early stage of the project. Ethics approval was granted by the Tokyo Institute of Technology Review Board (2022150). Due to the strict non-disclosure agreement, the explanation about the interface is suppressed in the present paper.

Following the procedure, we created a first version scenario, which roughly describe how a user (operator) behaves in a hypothetical work situation. Table 1 shows a part of the scenario and design implications obtained by interpreting the scenario. Italic words in parentheses in the scenario shows items of PSFs used to create the piece of episode. For example, "work hours" included in PSFs can be treated as a critical factor relating to the context of use of the monitoring system. From this item (work hours), we could recognize that the working hours and related human factors had to be included in the usage episodes. Very similar idea could be also obtained from the PSFs items of shit rotation, duration of stress and long, uneventful vigilance periods. By synthesizing the ideas, we could make the first sentence of the scenario (see Table 1).

Specifications Elicitation Process

By examining the stories which vividly describe how an operator behaves, we could obtain insights that were useful for determination of specifications.

Table 1. Example scenario and elicited implications.

Scenario created -first version-	Implications for design
I frequently experience on intervention to autonomous vehicles every day (*work hours, shift rotation, duration of stress, long, uneventful vigilance periods*). The types of the interventions are very different (*anticipatory requirements, interpretation, complexity*). I feel a kind of pressure since I need to understand the reason why the autonomous system calls me immediately based on very limited information (*long and short-term memory, task speed*). Sometimes, the reason is very severe (*task criticality*). Caused by this, I sometimes feel impatient and irritated during working (*stress*). Honestly speaking, I want a little more information which help me to understand the situation/reason by which the system calls me (*procedure required*)… (omit)	Less workload should be avoided to keep vigilance level. Warning level should be defined appropriately. Knowledge of typical adverse events should be taught in advance. Appropriate wording of adverse events, which is consistent with users' mental model, is necessary… (omit)
One day in the afternoon, the system calls me with a warning sound (*perceptual requirements, cautions and warnings, fatigue*). I look at the driving information display immediately, and try to recognize what adverse event occurs (*procedure required*). I can guess that the event is something relating to a pedestrian who can be seen in front of the car (*interpretation, state of current practice or skill*). The only thing I can understand quickly is that the event occurs at an intersection since the monitoring system shows a map around the car (*perceptual requirements, decision making*). I really feel nervous because something happens where a pedestrian is involved (*interpretation, stress, task criticality*). But still what really happens is not clear… (omit)	Present scene, scene when the adverse event occurs, and relating contexts are necessary to understand the situation. Scenes transitions for at least a few seconds seems necessary. Clear mark that highlights the pedestrian is needed. In addition to visual information, auditory information should be perceived by the operator… (omit)

One of critical implications is underlined in Table 1. Reading the corresponding part of the scenario, we can easily generate the following question: How does the operator identify the current situation? It is obvious that the seeing the present scene is not sufficient because the objects involved in the adverse event (e.g., pedestrian) may have already left from the view sight. This lets us generate a desirable design concept of interface enabling operators to understand the situation immediately by showing both of present status and additional status information for appropriate time interval in which the specific adverse event is valid. By breaking down the design concept, the following basic specifications could be elicited:

- Information display showing present status constantly.
- Additional information display showing warning message of adverse event, and status before, during and after the adverse event whenever necessary.

Generation of First Version Prototype

Reflecting the specifications elicited from the scenario, the first version of the prototype was developed. Figure 3 shows a schematic description of the prototype. Caused by the NDA, only a part of specifications which are directly connected with the output of above-mentioned design processes are roughly described in the figure. One of the notable features equipped in the prototype is an automatic scene playing in the sub display, which allows an operator to take over from the autonomous vehicles controlling systems smoothly.

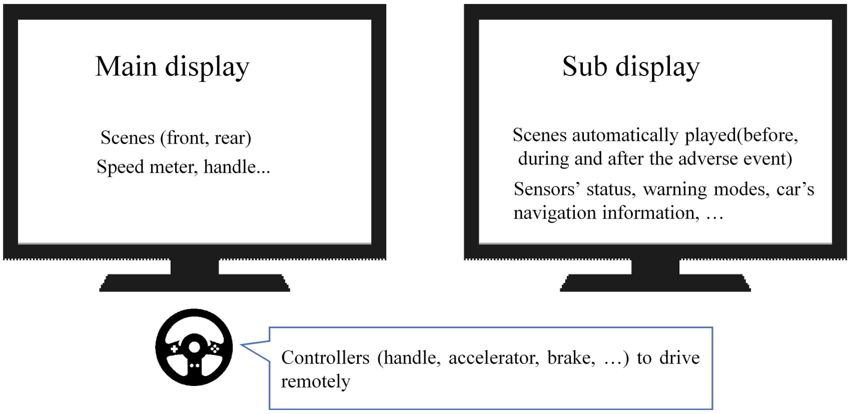

Figure 3: Schematic description of the prototype.

CONCLUSION

As well known in human factors and ergonomics societies, a critical principle of human-centred design, in general, is an iterative design process. We are now performing iterative design in which both of scenarios and prototypes are refined. The keys of our approach are as follows: (i) operators desirable behaviors are always focused and they are vividly described in scenarios, and (ii) the consistency among scenarios are always kept since the identical PSFs are used as references at any phases, which contributes to efficient and effective design processes. Though the paper does not show details of the design processes, this can show the essence of the design methodology, which is useful for new products/systems design as was recognized by the collaborating practitioners.

ACKNOWLEDGMENT

This research was supported by Mitsubishi Electronic Corporation. We would like to acknowledge Kohei Tanaka, Kitamura Yoshiaki, Kazuyo Yoshimura for their great effort to this research.

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