Military Vehicle Dashboard Design Using Semantics Method in Cognitive Ergonomics Framework

Billy Muhamad Iqbal(✉), Amalia Suzianti, and Boy Nurtjahyo

Department of Industrial Engineering, Faculty of Engineering,
Universitas Indonesia, Depok 16424, Indonesia
billy.iqbal87@gmail.com, suzianti@eng.ui.ac.id,
boy.nurtjahyo@ui.ac.id

Abstract. Indonesia requires innovation and revitalization for the military vehicles that match the performance of the Indonesian Armed Forces (TNI) in securing the sovereignty of the Republic of Indonesia. Based on this fact, the need for good vehicle use, effective and efficient is necessary, by the fact the Indonesian military vehicles is commonly old that have limited function and ergonomics. The new vehicle purchased from abroad is also less fit for the soldier's ergonomic profile. The study aimed to design one of the main parts that are considered most representative of a military vehicle to fit between the vehicle function and the profile of soldiers. This study aims to design an instrument Human-Machine Interface in the form of a dashboard with semantic methods and evaluated on a military vehicle with a virtual method in order to maximize the functions of the Human-Machine Interaction in the vehicle in order to improve the performance of the military vehicles that will maximize the ability of the military in using their main combat tools

Keywords: Cognitive ergonomics · Product design · Military vehicle · Semantics design · Human machine interface

1 Introduction

In essence, the Indonesian military vehicle R & D projects have been providing the best in terms of all sorts of considerations in the design, but the human factor is often the case as the user does not become one of the main principal consideration, it can be found on some vehicles designed by the domestic retrofit projects or revitalization older vehicles as well as research and development project of a new military vehicle. Integration of vehicle systems with only limited user anthropometry calculations and design dimensions of space only. Problems of noise, workload, and the efficiency and effectiveness of cognitive performance are hardly considered. In fact, the optimization of system integration and design of each system becomes very important, because the effectiveness and efficiency of use of the vehicle and the system is closely related to its user (MacLeod 2003). In order for the vehicle to run and function properly then the vehicle must be able to accommodate various sizes of humans as users (Punter and Oudenhuijzen 2000).

D. Harris (Ed.): EPCE 2015, LNAI 9174, pp. 152–163, 2015.
DOI: 10.1007/978-3-319-20373-7_15

Based on this background, the formulation of the problem obtained on this research, the problem is lacking of a specific method in the application of ergonomics in the design of the military vehicles interface (dashboard) in Indonesia. There was an absence of effective and easy method as guidance for the interface design of military vehicles that use the rules of basic aspects of cognitive ergonomics in its design. Therefore, this study aimed at the design of the dashboard interface with aspects of cognitive ergonomics, as the optimization of the functionality and performance of an interface that bridges between special functions of a military vehicle (special vehicle) with its user and the use of semantics method in the design process to integrate the rules of ergonomics cognitive into the design.

2 Literature Review

Various factors affect the performance of users, as cognitive in the operation of military vehicles interface. Factors that taken as precedence in the design of this vehicle is the comfort aspect which consists of user independency from a variety of noise such as the placement of various instruments in the dashboard that not appropriate, or writing and symbols that not represent the function correctly, because each type of instrument input has a different response time (Bacon 2011), and the false information will delay the response time.

Next is a fail protection, an assurance when vehicle in an error condition or a severe accident (Hoffenson 2012). All of these factors serve as benchmarks in achieving necessary ergonomics system to optimize the design of the interface of military vehicles. Vehicles that designed by considering the various dimensions of human beings, said to be able to run and function well (Punter and Oudenhuijzen 2000), however, in extreme conditions such as on military vehicles, the mental state, will affect the performance and decision-making, therefore, consideration of cognitive ergonomics is also very necessary for the working conditions and a hostile environment filled with stress (Alfredson 2011).

Design process begins with finding the right concept as an image. This image obtained from the information visually and generally the image that will be used as a concept is sought in two ways, namely content-based image retrieval and text-based image retrieval (Setchi et al. 2011). The methods that commonly used to define a meaning in terms of the use of an object that produced is the semantics method (Giard 1990). Semantics method, change the impression that appear visually into an informative description as a reference for the creation of a new design concept and directed (Setchi et al. 2011), this method can also pick up information on the user's cognitive and make new products more effectively and efficiently without eliminate the cognitive information.

The Military of Indonesia as the user has the optimum area within operational range of HMI (Reed 2003). However, different conditions, will lead to differences in time-motion, as in a stressful situation or a state of emergency, and IVIS (In Vehicle Information System) as one of the important elements in both the commercial vehicle and military vehicles, whose function can be a distraction or interruption in the operation of the vehicle (Brostrom et al. 2011) so the instruments that support the mental models or perceptions of the user is required (Alfredson 2011) to facilitate user cognitive and to reduce user error. However, not only that, the product design process requires a synergy between the knowledge management, supervision and good design practices, so that the development of a design can produce good output (Chandrasegaran et al. 2012).

2.1 Cognitive Ergonomics

Cognitive here has a meaning that is an ability to maintain and use the knowledge in an information processing system in humans. Cognitive ergonomics discusses how human performance on cognition of an artifact suggests there are several things that affect how information is transferred and processed on each individual, which is:

Situation Awareness and Attention. According to Endsley (1995), "situation awareness" is the perception of the elements in an environment by using a measure of time and distance, and understanding the purpose of these elements to interpret the condition of the individual to take further action. The process involves three levels of information processing, i.e.:

- Perceptions of the elements of a work environment or system.
- Understand current conditions.
- Estimating situation will happen next for the development that will come.

Mental Model. Mental models are the translation subjectively by a person against a system based on their knowledge or previous experience to form a perception of the approach, and the use of a person's perspective on a system or a product/artifact. So a design that takes into account of mental model of the artifact can be said is a design that has the capability of efficient interaction (Cañas 2011).

Interaction with Artifacts. In general, what is meant by learning is the process of information retrieval, according to Norman (1986) there are at least three forms of learning with regard to an artifact, i.e.:

- Accretion, information retrieval processes that accumulated and tend to be a fact.
- Tuning, learning process by adapting the gradually actions that we take to an artifact and use the information obtained to develop the performance of the action taken.
- Restructuring, is a learning process with the highest and most difficult stages, which is learning by discovery of an artifact conceptual relations.

Decision Making. Decision-making or "Control of Critical Incidents", which is how a person retains a full control over the activities that will be performed when the critical moment occur. Categories of critical moment according to Cañas (2011) are the decision-making in critical condition or under pressure of time and a bit of information to prevent the consequences of the occurrence of a fatal error.

Mental Workload and Stress. Every human being has a number of cognitive resources in which there is an active process, and errors that occur due to excessive load on the "Working memory" or working memory on individual causes of mental workload and stress (adapted from Olson and Olson 1990). Limitations of human performance can lead to fatigue, monotony and stress are generally caused by the limited time (at work), which is available as well as the ability of subjective interest in a job are an acute stressor (Cañas 2011).

2.2 Cognitive Information

Shannon-Weaver communication theory (1986) puts communication as something broad and is not limited by the medium, so if the theory is linked to how the relationship of users and artifacts (products) then what happens next is when someone is trying to figure out a product or function of a specific product and successful, then the cognitive communication can be said to have occurred and cognitive information has been conveyed to others. This predictive process, information that translated by the cognitive brain function can be referred as cognitive information, because the information is purely the result of ideas and not the written or textual information (Fig. 1).

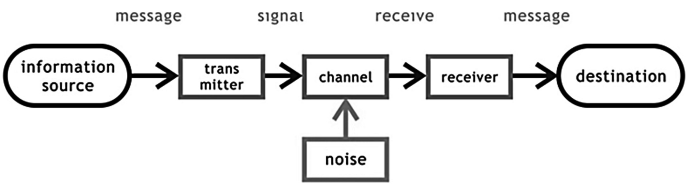

Fig. 1. Shannon-Weaver communication model

According to Shannon and Weaver, information reaching process does not just get to the destination from the source, there are noises or disturbances that commonly occur in the channel of information for ongoing information process. According to the Shannon-Weaver also that there are three levels within the communication problems, namely:

- Technical Problems: How accurate is the symbol of the information can be sent (so it can be translated correctly, Res.).
- Semantics Problem: How accurate is the symbol that sent, represent the meaning/ message that expected.
- Effectivity Problem: How effective is the message received affects the behavior as expected.

Then according to Cañas (2011) there are three kinds of mistakes or errors that may occur in the human /user as a channel, namely:

- Error based on Skill: Errors due to insufficient user capability
- Error based on Rules: Errors due to wrong in perceiving/translating a function under certain conditions.
- Error based on Knowledge: Errors due to lack of knowledge/understanding of the user.

2.3 Semantics Method

Research on semantics that has been done shows that semantics is a substance in the communication between the product and its users through cognitive meaning, so the this semantics can be referred as a product language (language of product)/design language (Syarief 2006), so the semantics are valid methods in building a better product attributes that can be defined explicitly or implicitly. These attributes include the meaning of visual function (visual form to convey the message mechanical), elements of a product (color, image, dimension, etc.) and the grammar of a product (consistency, affordance, flexibility, etc.).

Language semantics is a product that can be used in both directions, i.e. as the product becomes a language translator and interpreter language, or grammar into a product. Therefore, the products semantics can be referred as the meaning of a product into its attributes, and the product attributes is consisting of:

- Function: each product has attributes function which can explain the purpose for which the product or artifact is made.
- Element: is an attribute that represents the elements in building a product such as shape, color, dimensions, and so on.
- Grammar: Grammar is the arrangement of words or keywords that are considered to represent a product of the purpose of the product are made. When a product are made for the upper class, people tend to insert a word that refers to something high like "classy", "elegance", "limited edition" and so on. These keywords can be a concept in the design and became the brand image of a product.

As a step for retrieving information in the product, in order to convert textual information into contextual information from or within a design, necessary tools or instrumentation that can translate or transform such information process is needed. There is some common instrumentation used in the semantics of products (Syarief 2006), which is:

- Image Board. this image board instrument used to communicate and express concepts/elements of a product that is intangible and abstract based on visual analysis of a set of images (photographs, drawings, etc.) that can represent human emotional response (Syarief 2006). Image board is built based on keywords from the human emotional responses such as "fun", "joyful", "dynamic", "masculine", "futuristic", "extreme", and so on. The keyword selection should be based on something that is measurable. Then the keywords are given its antonym to provide a comparison in laying image.
- VPE (visual perception evaluation). VPE is a tool that can be used as an evaluative instrument for a product /artifact or design. VPE is a descriptive instrument, semi-objective and comparative. The VPE also has a function to obtain more objective visual stimulation through perceptual identification (visual sensation), experiential (User-related knowledge), and preferential (like-dislike) (Syarief 2006). VPE instrument can be modified as needed, such as the number of keywords, or use of the parts that required, such as certain parts for the expert respondents (interview with Windhu P, March 10th, 2014 in PINDAD).

3 Research Method

3.1 Subject and Tools

The subjects in this study is an interface system (dashboard) of tactical military vehicle made in Indonesia which has an authentic design but fundamentally still refers to vehicles that have been there before. Tactical Vehicle Komodo 4 × 4 PINDAD has a specifications that was tailored to the needs of the military.

The main tools that used to conduct this research is software CAD (Computer-Aided Design) Autodesk Product Design Suite ™ which contains various software tools to help design products and Biped Simulation to simulate the human against the use of the product. The output of this software is a still-frame rendering as an aid for visual analysis.

3.2 Design Specification

Firstly, semantic method's image board will be use. Keywords for dashboard design have been selected based on theme designs who want to redesign the dashboard with a design that has a novelty. This is because Tactical Vehicle Komodo is a new vehicle. Because of that the selected keywords is "New" with the opposite word "Old" as a comparison. The next keyword is "Military" in order to keep the design of the dashboard remains on track for the design of military objects, so it is not recognized as a design element to another vehicle and for this keyword is given as the opposite of "Civil" (Figs. 2 and 3).

The second step is determining the value of initial design using VPE questionnaire. Initial dashboard design assessed by VPE method for the determination of the design

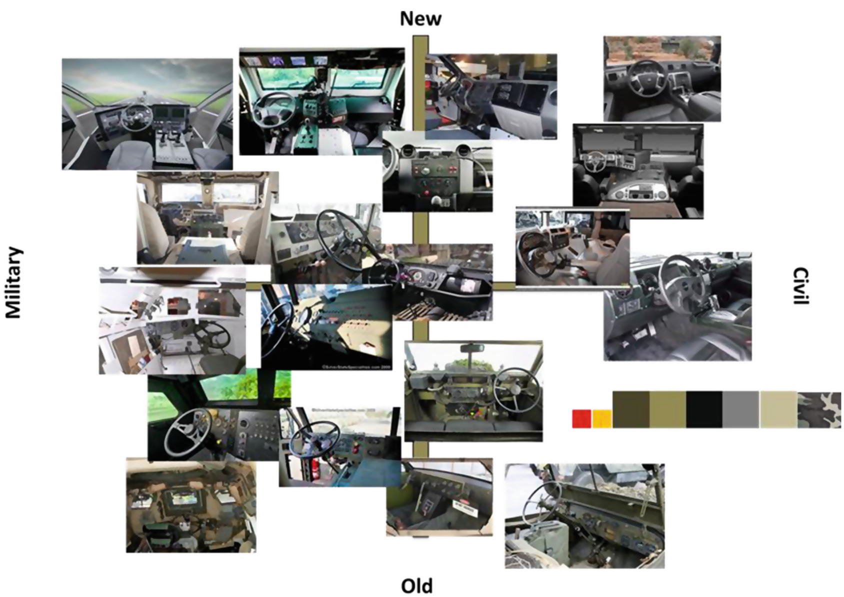

Fig. 2. Image board for determine the dashboard design specification

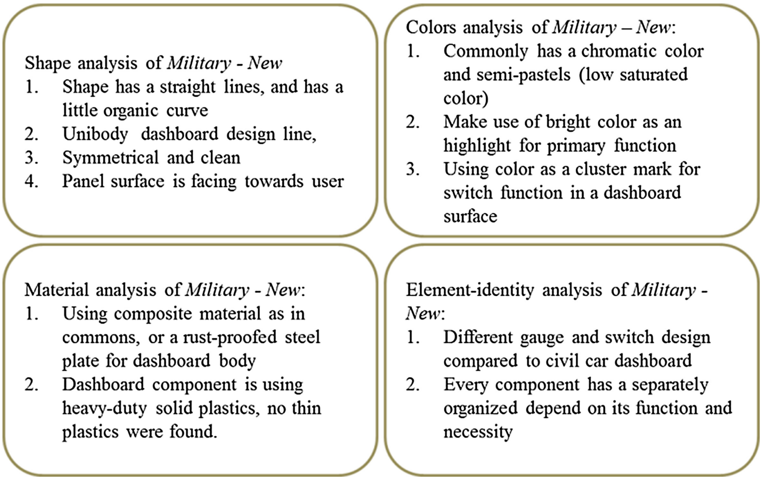

Fig. 3. Result of analysis of image from Military-New keywords from the image board

basis, the keyword is adapted from the journal of Yamaoka (2011) regarding the design of a good interface and ergonomic factors to human cognition. The respondents are tactical vehicle designer at PT. PINDAD and several experts in the field of military vehicle interface generate the following values:

The third step is determining the dashboard component layout. This step was done by the Activity Relationship Chart (ARC). ARC serves to translate the activities associated with the use of elements, features, room, or facility on a system. The designs of the military vehicles dashboard utilize ARC as an estimator dashboard elements layout (Fig. 4).

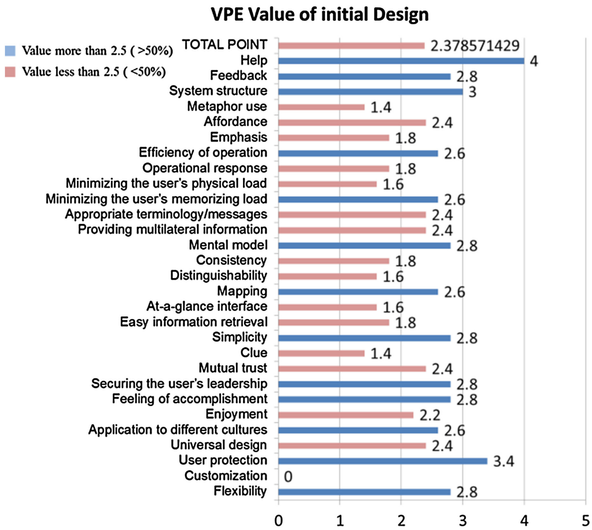

Fig. 4. VPE value of dashboard initial design

4 Result and Discussions

First step is redesign the panel and clusters grouping for better conform to cognitive ergonomic value. And after that the process will move to redesign the whole dashboard. The design was made totaling four pieces with a variety of configurations obtained from the layout diagram elements are made based on the ARC and the level of interest of the dashboard elements. The design will be made to adapt the results of the analysis of the image board to guide the design visually, so that in cognitive way, ergonomic design of the result is fixed (Figs. 5, 6 and 7).

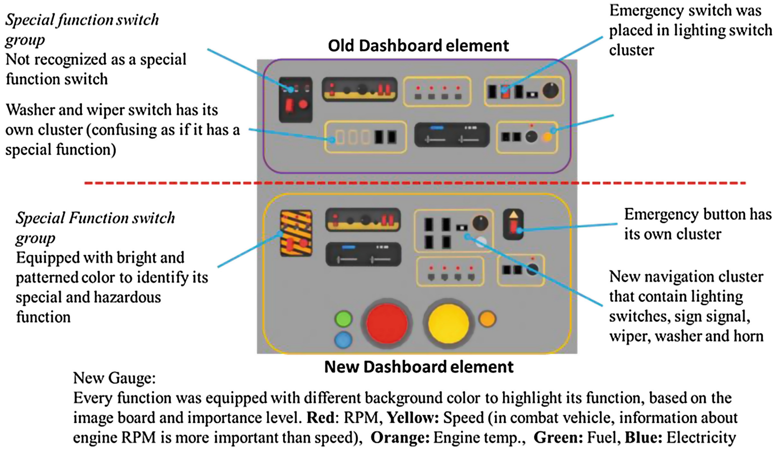

Fig. 5. Comparison of old and new dashboard element regarding the value taken from cognitive ergonomics and semantics method (image board).

Fig. 6. Three-dimensional models of 1st, 2nd, 3rd and 4th design (from above to below, left to right) and the initial design (center).

The results of a design sketch then turned into a three-dimensional model with size adjusted to the original dashboard. The new design is adapted from previously established specifications, was expected to give better results than predecessor designs and assessed by the expert using a VPE.

VPE value of the new design is based on principles of cognitive ergonomics by using semantics, showed a significant result compared to the value of early design.

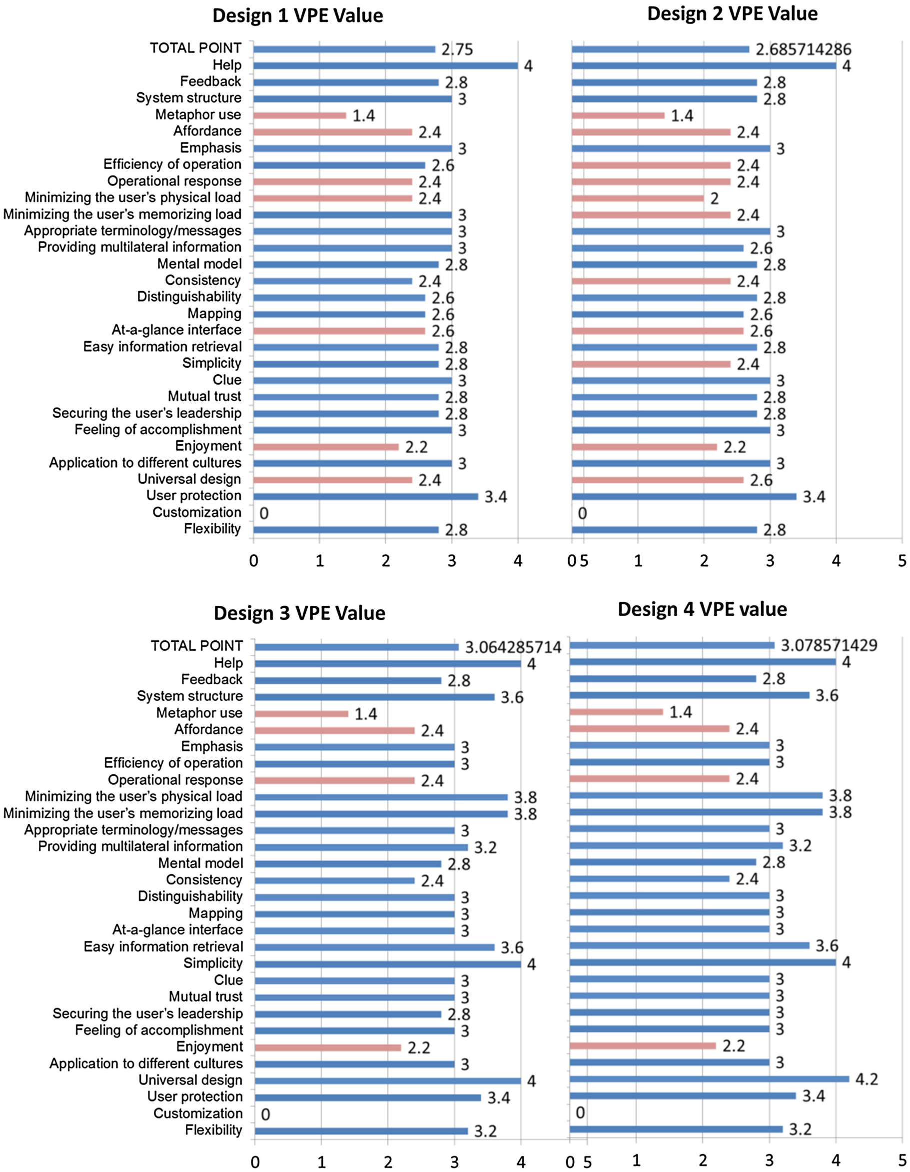

Fig. 7. 1st, 2nd, 3rd and 4th design values from the VPE questionnaire

The early design is designed without method semantics and cognitive ergonomics rules. Significant value in the opinion of experts is: if the total value exceeds 50 % of the total value of the sum value of each keyword, so that in a view of design assessment, the 1st to 4th design is considered to have good design. The statement was reinforced by the table that shows the new dashboard design accessibility compared with early design of the dashboard.

5 Conclusions

The design process is guided by the semantics method has been successfully carried out and resulted in a better design than the initial design, by utilizing the image board to guide the design and assessment based on VPE (Visual Perception Evaluation) questionnaires as an assessment of the cognitive ergonomics. The evaluation resulted in values: initial design get the value of 2.38 out of 5, while the fourth made a new design variant respectively - each getting the value of 2.75, 2.68, 3.06 and 3.07 of the scale value 5. The value indicates that the method can be use and has a valid manner. So, the design process can be applied to the design of the dashboard in other military vehicles

Table 1. Table of dashboard element accessibility from initial design to a new design

Initial Design

No	Element	Users	Visible	Reachable
1	Gauge-Meter Cluster	Driver	x	✓
2	Drivetrain Switch	Driver	✓	✓
3	Electrical Switch	Driver	✓	✓
4	Navigation Switch	Driver	✓	✓
5	Emergency Switch	Both Personnel	x	x
6	Special Function Switch	Watcher (Gunner)	✓	✓
7	Multi Purpose Display	Both Personnel	x	x
8	Communication Panel	Watcher (Gunner)	✓	✓

1st Design

No	Element	Users	Visible	Reachable
1	Gauge-Meter Cluster	Driver	✓	✓
2	Drivetrain Switch	Driver	✓	✓
3	Electrical Switch	Driver	✓	✓
4	Navigation Switch	Driver	✓	✓
5	Emergency Switch	Both Personnel	x	x
6	Special Function Switch	Watcher (Gunner)	✓	✓
7	Multi Purpose Display	Both Personnel	x	x
8	Communication Panel	Watcher (Gunner)	✓	✓

2nd Design

No	Element	Users	Visible	Reachable
1	Gauge-Meter Cluster	Driver	✓	✓
2	Drivetrain Switch	Driver	✓	✓
3	Electrical Switch	Driver	✓	✓
4	Navigation Switch	Driver	✓	✓
5	Emergency Switch	Both Personnel	x	✓
6	Special Function Switch	Watcher (Gunner)	✓	✓
7	Multi Purpose Display	Both Personnel	x	x
8	Communication Panel	Watcher (Gunner)	✓	✓

3rd Design

No	Element	Users	Visible	Reachable
1	Gauge-Meter Cluster	Driver	✓	✓
2	Drivetrain Switch	Driver	✓	✓
3	Electrical Switch	Driver	✓	✓
4	Navigation Switch	Driver	✓	✓
5	Emergency Switch	Both Personnel	x	x
6	Special Function Switch	Watcher (Gunner)	✓	✓
7	Multi Purpose Display	Both Personnel	✓	✓
8	Communication Panel	Watcher (Gunner)	✓	✓

4th design

No	Element	Users	Visible	Reachable
1	Gauge-Meter Cluster	Driver	✓	✓
2	Drivetrain Switch	Driver	✓	✓
3	Electrical Switch	Driver	✓	✓
4	Navigation Switch	Driver	✓	✓
5	Emergency Switch	Both Personnel	✓	✓
6	Special Function Switch	Watcher (Gunner)	✓	✓
7	Multi Purpose Display	Both Personnel	✓	✓
8	Communication Panel	Watcher (Gunner)	✓	✓

while considering the ergonomics (anthropometry) and cognitive ergonomics. Therefore, the VPE (visual perception evaluation) questionnaire in this study has been given to the military vehicles expert and military vehicle interface expert are few in number. So, for the future research, more expert respondents are needed and considerations to using other methods for validation are required. This study with a VPE questionnaire prove that the behavior of users in viewing or using of a product can be led or directed in accordance with the interest of product use, thereby providing the opportunity for further research, how a product can alter the behavior of its users (Table 1).

References

Alfredson, J., Holmberg, J., Andersson, R., Wikforss, M.: Applied cognitive ergonomics design principles for fighter aircraft. In: Harris, D. (ed.) Engin. Psychol. and Cog. Ergonomics, HCII 2011. LNCS, vol. 6781, pp. 473–483. Springer, Heidelberg (2011)

Bacon, L., Vu, K.-P.L.: Movement time for different input devices. In: Harris, D. (ed.) Engin. Psychol. and Cog. Ergonomics, HCII 2011. LNCS, vol. 6781, pp. 3–9. Springer, Heidelberg (2011)

Brostrom, R., Bengtsson, P., Axelsson, J.: Correlation between safety assessments in the drive car interaction design process. Appl. Ergon. **42**, 575–582 (2011)

Cañas, J.J., Velichkovsky, B.B., Velichkovsky, B.M.: Human Factors and Ergonomics. Handb. Appl. Psychol. 316–-337 (2011)

Chandrasegaran, S.K., Ramania, K., Sriram, R.D., Horváth, I., Bernard, A., Harik, R.F., Gao, W.: The evolution, challenges, and future af knowledge representation in product design systems. Comput. Aided Des. **45**(2013), 204–228 (2012)

Endsley, M.: Toward a theory of situation awareness in dynamic systems. Hum. Factors **37**, 32–64 (1995)

Giard, J.: Product semantics and communication: matching the meaning to signal. In: Vihma, S. (ed.) Semantic Visions in Design, Symposium on Design Research and Semiotics, pp. 2–6. Helsinki (1990)

Hoffenson, S.: Safety considerations in optimal automotive vehicle design. ProQuest Dissertations and theses (2012). ProQuest Dissertations and theses Full Text

MacLeod, I.S.: Real-world effectiveness of ergonomic methods. Appl. Ergon. J. **34**, 465–477 (2003)

Norman, D.A.: Cognitive engineering. In: Norman, D.A., Draper, S.W. (eds.) User Centred System Design, Lawrence Erlbaum Associates. Hillsdale, NJ (1986)

Olson, J.R., Olson, G.M.: The growth of cognitive modelling in human computer interaction since GOMS. Hum. Comput. Interact. **5**, 221–265 (1990)

Punter, P.A.J., Oudenhuijzen, A.J.K: Computer-assisted ergonomic analysis for vehicle interior design. In: Proceedings of the Human Factors and Ergonomics Society, Annual Meeting; 3, ProQuest, p. 345 (2000)

Reed, M.P., Matthew B.P., Don B.C.: A new approach to modeling driver reach. SAE Technical Paper Series 2003-01-0587 (2003)

Setchi, R., Tang, Q., Stankoy, I.: Semantic-based information retrieval in support of concept design. Adv. Eng. Inform. **25**(2011), 131–146 (2011)

Shannon, C.E., Weaver, W.: The Mathematical Theory of Communication. University of Illinois Press, Urbana, IL (1949)

Syarief, A.: Semantika Produk I & II. Bahan ajar mata kuliah Semantika Produk. Desain Produk ITB. Bandung (2006)

Yamaoka, T.: Manufacturing attractive products logically by using human design technology: a case of japanese methodology. In: Human Factors and Ergonomics in Consumer Product Design: Methods and Techniques, pp. 22–36 (2011)