Using Technologically Related Products from Other Domains (TeRPODs) as Inspirations for Technology-push Product Concept Generation

기술주도혁신의 신제품 컨셉 결정을 위한 기술적으로

연관된 타도메인 제품들을 이용한 Ideation 기법

지도교수 박 우 진

이 논문을 공학석사 학위논문으로 제출함

2019 년 11 월

서울대학교 대학원

산업공학과

이 민 호

이민호의 공학석사 학위논문을 인준함

2019 년 12 월

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2020 년 2 월

서울대학교 대학원

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이 민 호

Abstract

Using Technologically Related Products from Other Domains (TeRPODs) as Inspirations for Technology-push Product Concept Generation

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This study presents a novel ideation aid termed technologically-related products from other domains (TeRPODs) for addressing technology-push product concept generation problems. A technology-push product concept generation problem is specified in terms of a new technology and a target product/industry/business domain for which the technology is to be utilized to create novel products/applications. TeRPODs are example applications of the technology collected from domains other than the target domain and serve as brainstorming stimuli during the new product concept generation. An experiment was conducted to empirically evaluate the utility of TeRPODs. The technology-push product concept generation problem considered was that of developing new applications of the augmented reality head-up display (AR HUD) technology for the automotive domain. Two groups of participants, one utilizing a relevant set of TeRPODs (the TeRPODs group) for ideation and the other (the control group) without any ideation aids, performed individual brainstorming to generate new automotive AR HUD application concepts. The TeRPODs group produced a significantly better ideation outcome than the control group in the quantity and diversity of ideation outcome. Also, the use of TeRPODs significantly improved usefulness, novelty, preference and profitability ratings of generated ideas. TeRPODs may serve as a useful ideation tool for technology-push inventions.

Keywords: Analogy; Brainstorming; Creativity; Ideation; Product concept generation; Technology-push product

Student Number: 2014-22646

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Chapter 1

Introduction

Numerous new products are launched in the market every day trying to gain the attention of the customers. Due to the fierce competition, creating products accomplishing commercial success is becoming increasingly difficult. One of the main forces driving new product development is technological innovation – technological change, along with changes in production organization, gives rise to new products and processes, and, thereby, reshapes the market and industry [1].

Two models, the demand-pull and technology-push models, have been suggested to account for new product development driven by technological innovation. The demand-pull model states that technological innovation should occur in order to meet known market demands and new products should be the outcomes of such innovation [2]. On the other hand, the technology-push model states that scientific advances lead to new technology development and the new technology is combined with commercial needs to yield new products [3, 4].

Many products developed by technology-push have accomplished great commercial success. Examples include products based on the touch screen technology [5] and nanomolecules of fullerenes [6]. The touch screen technology has been widely applied to various electronics products and has become part of people's everyday life. NanoTex Corporation, which produced the nanomolecules in large scale, made great profits by broadening the scope of the product's applications. Also, numerous technology-push products have been and are being created on the basis of the Internet of Things (IoT) [7], microelectromechanical systems (MEMS) [8], and autonomous driving [9] technologies.

From 2012 to 2017, there have been more than two million technology patent applications in a year, and half of them have been granted [10]. Given the abundance of new technologies, the ability to develop new products by 'technology-push' is becoming an increasingly important element of an enterprise's overall competency.

Despite the importance, however, new product development by technology-push presents some difficult challenges to entrepreneurs. One such difficulty lies in the generation of the new product concepts in terms of product value, functions, behaviors, and/or structure. In the demand-pull model, generating new product concepts is relatively easy as the needs of consumers are known in advance. However, in technology-push, typically, little such information is available in advance, and, in many cases, new product concept generation requires the product developer to make inferences about possible, not-so-evident applications of a given technology for a domain that has not seen the technology's applications before. Because of this, technology-push invention is known to be difficult and have great risks of failure [4, 11].

Across different industries and contexts, various ideation methods and tools are being utilized to support new product concept generation [12, 13]. Idea generation techniques, such as brainstorming [14], lateral thinking [15], brainwriting [16], braindrawing [17], morphological analysis [18], and synectics [19], intend to help ideators broaden horizons of thinking in defining problems and generating solution alternatives [20]. Other methods help ideators access and utilize external knowledge for ideation; these methods provide knowledge in the form of design heuristics [21-

27]. SCAMPER [28], TRIZ 40 design principles [29], Transformation design theory [30] and the design heuristics for X (DHSfX) [31] are some examples of design heuristics sets. Different brainstorming stimuli, such as questions, instructions, visual images and tangible objects, have been utilized in order to inspire the ideators during ideation and thereby improve their ideation performance [32-37]. Recently, various software tools have also been developed to help with ideation [38, 39]. Such brainstorming stimuli help generate new ideas through problem reformulation/re-representation, expansion of scope of thinking, free associations and/or analogical reasoning.

Despite the availability of various ideation methods and tools above, however, very few of them seem to specifically target the problem of technology-push product concept generation – the authors are not aware of any that include a procedure, mechanism or feature designed to facilitate relating a new technology to a previously unrelated business/industry domain and making inferences about the technology's possible applications in the domain.

As an effort to support product concept generation for technology-push product development, the current study proposes a new product concept ideation tool termed TeRPODs, which stands for technologically related products from other domains. When a technology-push product concept generation problem is specified in terms of a new technology and a target business/industry domain for which the technology is to be utilized to create novel products/applications, example applications of the technology (example products) in domains other than the target domain are collected as TeRPODs. Product developers/designers can then utilize the TeRPODs as brainstorming stimuli during new product concept generation.

The rest of the article is organized as follows: Section 2 provides a literature review of previous ideation studies with a focus on brainstorming and brainstorming stimuli.

Section 3 describes what TeRPODs are and presents methods for finding and using them in brainstorming for technology-push product concept generation. In Section 4, an empirical evaluation study conducted to demonstrate the utility of TeRPODs is described. Finally, Section 5 provides a discussion.

Chapter 2

Past Research on Brainstorming and Brainstorming Stimuli

As mentioned earlier, various ideation methods are currently being used for new product concept generation and other design/problem solving activities. Among these existing methods, brainstorming is one of the most widely-used one [40-43]. In addition to the standard group brainstorming procedure, many variants of brainstorming are being used, including: the individual brainstorming [44], directed brainstorming [45], brainwriting [16], braindrawing [17] and bodystorming methods [46].

Different types of brainstorming stimuli have been utilized to enhance brainstorming outcome [47-50]. Some stimuli are presented in the form of questions concerning different aspects of an ideation problem. Well-chosen questions may help the ideator examine a problem from different angles and thereby expand the scope of thinking. Dennis et al. [32] demonstrated the utility of representing an ideation problem as a set of questions in improving brainstorming outcome. Other stimuli are in the form of instructions, which prompt the ideator to consider/reconsider various factors surrounding a given ideation problem, including causes, assumptions, properties and attributes. Potter [33] showed that ideating main causes of a problematic situation in advance could enhance the outcome of brainstorming for finding solutions.

Much research has been conducted on utilizing analogies as stimuli for idea generation. The WordTree design-by-analogy method [51, 52] provided a process for identifying useful analogies by re-representing the key functions of a product to be developed. Casakin and Goldschmidt [34] showed that visual analogy could facilitate design problem-solving. Verhaegen et al. [53] used product characteristics, automatically and systematically identified candidate products from patent database, for design-by-analogy. Also, Murphy et al. [54] developed a new method to extract functional analogies from data sources such as patents. Bio-inspired design, which translates the knowledge obtained from the natural world into new innovations, can be regarded as design by analogy [55-58].

In using analogies as stimuli, analogical distance, that is, topical relatedness of a stimulus to a given problem, is known to systematically affect the novelty of ideas generated. In general, distant analogies tend to lead to producing novel ideas [34-35, 49, 59-63]. However, this is so within a certain limit – excessively distant analogies may not help produce ideas [34]. Thus, selecting stimuli with adequate distance or topical relatedness may be important [64-66].

Despite their utility, brainstorming stimuli may give rise to design fixation [67, 68] - in other words, a brainstorming stimulus may limit the designer's ability to broadly explore the solution space [69]. Several previous studies have shown that the use of analogy can lead to design fixation [68, 70-75]. Different approaches have been proposed to address the problem of design fixation during the use of brainstorming stimuli [76-78]. Smith and Linsey [76] introduced the cognitive principle, "forgetting fixation", which is to shift contexts (inhibition, interference, and context change) to overcome fixation. Youmans [77] reveled that design with physical prototyping materials during the conceptual design process reduced fixation. Knoblich et al. [78] found that incubation (taking a break) mitigated fixation.

Chapter 3

Utilizing TeRPODs for technology-push product concept generation

3.1 TeRPODs as brainstorming stimuli

This study proposes using a new type of brainstorming stimuli termed TeRPODs, which stands for Technologically-Related Products from Other Domains. When a technology-push product concept generation problem is given in terms of a target domain (a product domain, an industry or a business domain) for new product development and a new technology to be utilized, relevant TeRPODs are chosen among commercially available/successful products that are based on the technology but are from domains other than the target domain.

It is hypothesized that TeRPODs, if used as brainstorming stimuli during technology-push product concept generation, can positively affect ideation outcome. This hypothesis is predicated upon the following reasoning: first, TeRPODs are by definition technologically related to the to-be-developed product concepts. Therefore, TeRPODs provide the ideators with important information about the technology, such as the values the technology created and the purposes that the technology served in different contexts. They also describe how the technology was implemented in or integrated into different products/systems. Such information at the levels of product value, function, behaviour and structure would greatly help the ideators discover possible relationships of the technology to the previously unrelated target domain and would further facilitate analogical transfer. Second, TeRPODs, while technologically related to the to-be-developed product concepts, differ from them in the product domain. This difference could help the ideator see the given product concept generation problem with a fresh eye, avoid fixations and get new insights about the potential use of the technology – it forces the ideator to adapt the ideas underlying the TeRPODs to the context of the given concept generation problem. Such cross-domain analogical reasoning is known to increase the likelihood of producing novel ideas [79]. Finally, TeRPODs are chosen among commercially available/successful products, and, therefore, represent examples of 'useful' inventions; the use of 'useful' inventions as brainstorming stimuli may help the ideators keep their focus on defining and creating customer values during the technology-push product concept generation, and, this in turn may lead to increasing the likelihood of producing useful concepts.

3.2 Technology-push product concept generation using TeRPODs

The procedure for preparing and utilizing TeRPODs for technology-push product concept generation is shown in Fig. 1, and the specific description is as follows:

Step 1) Defining the technology-push product concept generation problem: at the outset, the individuals in charge of finding and documenting TeRPODs (the TeRPODs curators) and the ideators generating product concepts work together to define the technology-push product concept generation problem – the curators and ideators can be the same individuals. The technology-push product concept generation problem must be specified in terms of a target domain (an industry, a product or a business) for new product development and a new technology to be utilized.

Step 2) Finding product examples from other domains: the curators search for candidate TeRPODs relevant to the technology-push product concept generation problem and collect documents containing information about them. This is conducted through keyword searches in different data sources, which include internet search engines, manufacturers' websites, product catalogues and technology magazines. The data sources and search keywords need to be determined on the basis of a preliminary study on the technology and its applications. Efforts should be made to identify a wide variety of applications of the technology. Subject matter experts may be able to help the curators with the preliminary study. Once a set of candidate TeRPODs covering a wide variety of applications is identified, then only those that are currently on the market or have achieved commercial success are selected.

Step 3) Defining TeRPODs: providing the collected products directly to the ideators may result in inefficient performance due to the excessive provision of similar product examples. Therefore, similar product examples should be grouped into one representative, TeRPOD, by similarity grouping methods such as KJ method. In summary, all the collected product examples are grouped together with similar ones, and each group is defined as a single TeRPOD.

Step 4) Preparing a TeRPOD brainstorming aid: the curators use the information about the TeRPODs identified in the previous step to develop a product concept ideation aid, which the ideators will use during the ensuing brainstorming activities. A simple yet effective ideation aid is a set of information cards each of which describes each TeRPOD in the set. Each card provides the TeRPOD's name and a graphical illustration of the product; the card also includes detailed verbal descriptions of the values the technology created and the purposes that the technology served in the particular context of the TeRPOD and the way the technology was implemented in or integrated into the product.

Step 5) Providing an orientation session: prior to brainstorming for concept generation, an orientation session is provided to the ideators. The orientation session describes the concept generation problem (the target domain and the new technology to be utilized) to the ideators. It also reminds them of the four basic principles of brainstorming process ('criticism is ruled out', 'freewheeling is welcome', 'quantity is wanted', and 'combination and improvement are sought') [14]. Also, the TeRPODs brainstorming aid (information cards) is provided to the ideators. The ideators study the content of the information cards. If the ideators and curators are different and the ideators have questions about the TeRPODs, the curators address them.

Step 6) Performing brainstorming with the TeRPODs brainstorming aid: the ideators perform brainstorming in group or individually utilizing the TeRPODs brainstorming aid. The ideators can consult the information cards at any time in the idea generation phase of the standard brainstorming procedure – other than this, the brainstorming process is identical to that of the standard brainstorming procedure [14]. The ideators are instructed to use the contents of the information cards as sources of inspiration as much as possible, and, in particular, are encouraged to make free associations and/or analogies using the information so as to generate technology-push product concepts. Sufficient time and necessary items, such as paper, pencil, etc. are provided. The ideators are allowed to express their ideas in different forms, including verbal descriptions and graphical images.

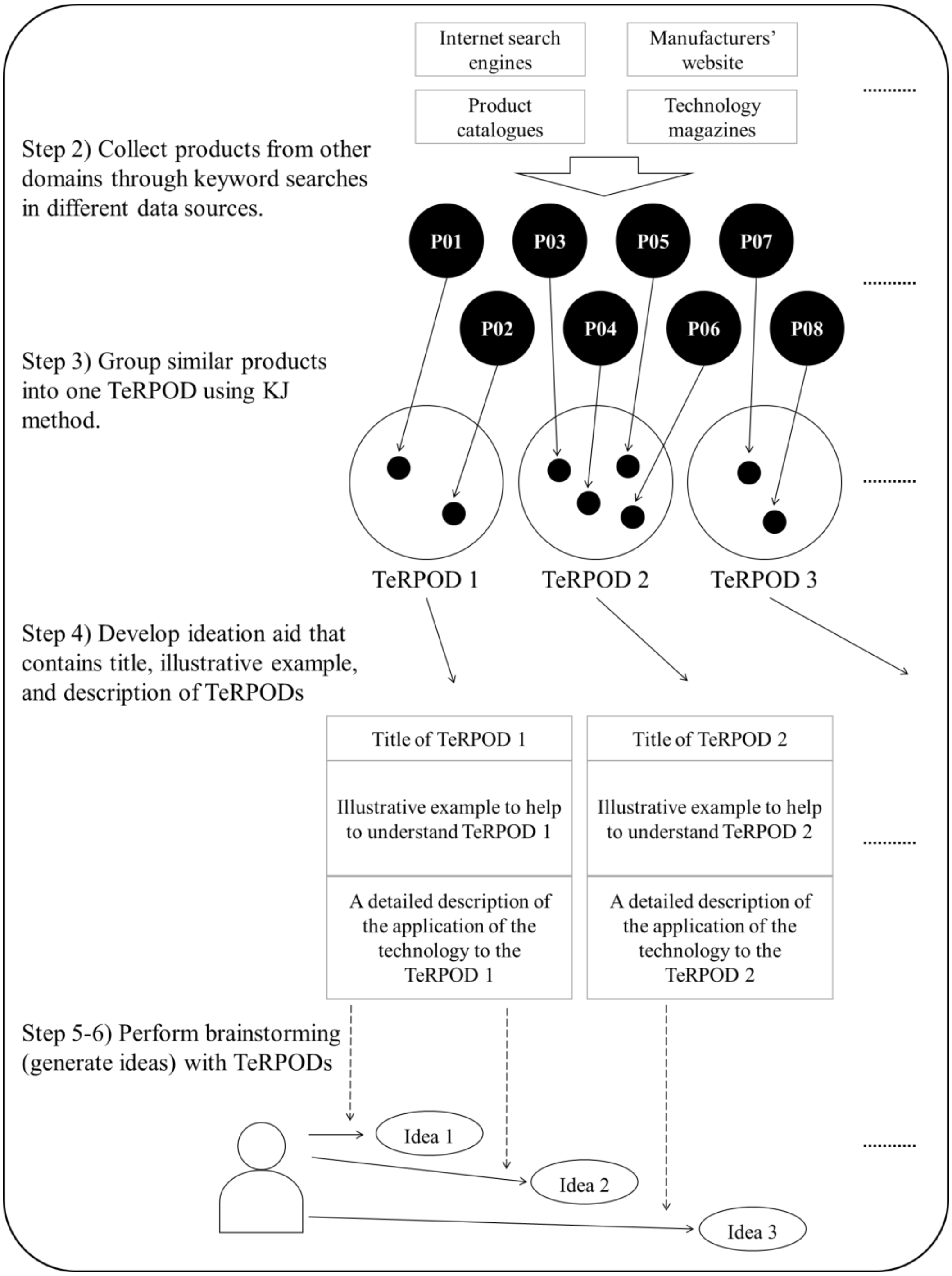


Figure 1: Flowchart of preparing and utilizing TeRPODs

Chapter 4

Evaluating the utility of TeRPODs

4.1 Experiment

An experiment was conducted to demonstrate the utility of TeRPODs as brainstorming stimuli for technology-push product concept generation. An example product concept generation problem was devised for the experiment. The target domain and the new technology were the automobile industry and the augmented reality head-up display (AR HUD) technology, respectively. Accordingly, the objective of ideation was to develop novel and useful automotive application concepts of the AR HUD technology.

The AR HUD technology has thus far gained considerable maturity on its hardware side; however, its possible automotive applications have not been fully explored. The technology seems to have the potential to give rise to many useful automotive functions and is widely recognized as a new opportunity for creating future innovative vehicles [61, 62] – some recent studies indeed proposed different driver assistance systems capitalizing on the technology [63-66]. Hence, the example problem represents an important real-world technology-push problem at the moment.

Thirty participants with a valid driver's license and more than one experience in brainstorming experiments participated in this experiment. Half of them (13 males and 2 females) were assigned to the control group. The other half (11 males and 4 females), the TeRPODs group. The control group performed individual brainstorming without any brainstorming stimuli; the TeRPODs group, on the other hand, used a set of TeRPODs relevant to the product concept generation problem as brainstorming stimuli. The participants' age and driving experience data are summarized for each participant group in Table 1.

Table 1: Summary of age and driving experience for each group

Group	Age (years)	Driving experience (years)
Control group	26.73 (3.79)	3.53 (2.29)
TeRPODs group	25.67 (2.58)	3.46 (2.03)

Note. Standard deviations are in parentheses.

Prior to individual brainstorming, an introduction/orientation session was held for each participant. The experimenters (the authors) provided each participant with a brief lecture on the brainstorming process and also its basic principles, such as focusing on the quantity of ideas, avoiding criticism, building on previously generated ideas and encouraging unusual ideas [14]. The participants, who have attended at least one engineering design lecture, had prior experience in conducting brainstorming; thus, the lecture was a reminder. Also, the experimenters provided a document describing the example technology-push product concept generation problem (generating automotive application concepts of the AR HUD technology) to each participant. Each participant read the document and the experimenters offered verbal explanations when needed. Finally, each participant in the TeRPODs group was familiarized with the concept of brainstorming stimuli through illustrative examples, and, then, was provided with the TeRPODs set specifically prepared for the example product concept generation problem.

The authors developed the TeRPODs set used in this study. The process used to develop the TeRPODs set was as follows: first, an initial internet search was conducted using the google search engine to identify the product/industry domains where the AR display technology was widely used. This initial search revealed that a large variety of AR applications existed in the domains of smart glasses and smartphone, and, also, descriptions of many such AR applications could be found in the Google Play and Apple Store websites. Second, a keywords search was conducted within the Google Play and Apple Store websites to find and collect descriptions of various AR applications in the smart glasses and smartphone domains. The keyword search formula was as follows: ('augmented reality' OR 'AR') AND ('display' OR 'visualization'). A variety of AR applications were identified and their text descriptions were collected. Third, the AR applications were grouped according to similarity and thirteen categories emerged from the grouping analysis. The KJ method [86] was utilized. Finally, for each category, a representative example was selected among the applications belonging to the category and its main idea was summarized in the form of an information card. Each card contained the title, visual illustration and verbal explanation of the corresponding AR application. The thirteen cards constituted the TeRPODs set used in this study. Three of them are shown in Fig. 2 as examples. The titles and short verbal descriptions of the thirteen TeRPODs are summarized in Table 2.

Figure 2: Three example TeRPOD cards

Table 2: Summary of the thirteen TeRPODs (AR applications) used in this study

No.	Title	Description
1	Real estate information	The application displays real estate information overlaid over real imagery
2	AR photographs	The user can take photos with AR images and share them via social networks
3	Augmented reality games	The user can experience digital game play in a real world environment
4	Nutritional information and recipes	The application displays recipe of foods and nutrition info of ingredients over real imagery
5	Digital pet	The user experiences raising a digital pet in a

		real world environment
6	Weather information	The application displays weather information (temperature, precipitation rate, humidity, etc.) in the user' forward field of view
7	Measurements	The application displays the length, width and height of an object over real imagery
8	Supplementary educational materials	The application displays supplementary materials (audios, videos, objects, etc.) for contents in physical books
9	Product design	The user can re-design real products by modifying the shape or color
10	Amenity information	The application indicates the locations of restaurants, tourist attractions and shopping malls over real imagery
11	Virtual fitting room	The user can try on digital clothes and modify their color and size
12	Anatomy	The application displays anatomical information over real imagery
13	Interior decoration	The user can arrange virtual furniture in a physical space

The main experiment trial followed immediately after the introduction/orientation session. Each participant was instructed to conduct individual brainstorming to generate product concepts (automotive applications of the AR HUD technology) and verbally describe produced ideas on paper, with drawings if necessary. An hour of time was given to all participants.

4.2 Data pre-processing, idea evaluation, research hypotheses and statistical analyses

The verbal data produced by the participants were pre-processed for ensuing idea evaluation. The objective of the data pre-processing was to produce two idea sets for each participant group: the set of all ideas and that of distinct ideas. For each participant group, the set of all ideas consisted of all ideas generated by the group members and included duplications – duplications were distinguished using the participant identification codes. The set of distinct ideas, on the other hand, was created by eliminating duplications within the set of all ideas. In the process of elimination, duplication was determined by only whether ideas provided the same function.

In the data pre-processing, for each participant, the authors analysed the corresponding verbal data into multiple passages or sentences, each describing a single idea - the drawings created by the participant were consulted to clarify the meaning of the verbal data when necessary. A single idea corresponded to a single function or a combination of 'interrelated' functions offered by an AR HUD application concept; a collection of multiple 'independent' functions was regarded as representing multiple, separate ideas. However, these ideas were excluded from the creative evaluation because one raw idea could affect the evaluation scores of multiple distributed ideas [75]. Each idea was labelled with a short phrase summarizing the content – for example, 'providing the user with the weather information.' Then, the two idea sets were created utilizing the ideas. The set sizes of the two idea sets were utilized as measures of quantity of ideation outcomes.

For each participant group, similarity-based grouping of ideas was conducted to identify idea bins. The idea bins represent distinct groups of similar ideas – the idea bins differ from one another in meaning but the ideas within each idea bin are similar [87]. Two ideas were grouped together as the same idea bin if they describe similar functions same as in the previous step of elimination of duplication ideas. For example, two ideas, 'providing the user with the weather information' and 'providing the user with the weather information when the vehicle enters the car wash' were grouped together as they were concerned with providing the same information despite the differences in contextual details; for these two ideas, the resulting idea bin was labelled as 'providing weather information.' The number of idea bins resulting from the similarity-based grouping were used to measure the diversity of ideation outcomes. A large number of idea bins indicates that the ideation process has generated many dissimilar ideas and is high in the diversity of ideation outcomes.

To support the reliability of idea categorization, cross-check validation was conducted [75]. After one researcher categorized the ideas, the 30% of the entire idea pairs were shown to another researcher and verified that the researcher had the same categorization of the idea as the previous researcher. As a result, 87% of agreement and a Cohen's Kappa of 0.71 were obtained from two researchers. It shows that the classification method of this study was reliable.

Each idea obtained from the data pre-processing was subjectively evaluated utilizing five idea evaluation criteria; novelty, usefulness, technical feasibility, preference, and profitability. Novelty and usefulness are widely known as two defining characteristics of creativity [88-90]. Multiple creativity studies evaluated ideas employing them [91-95]. Technical feasibility refers to whether or not the technologies needed for the realization of a proposed idea are currently available, and, thus, is an important criterion in assessing an idea's practical value. Some previous studies evaluated new product concepts in technical feasibility [96-98]. Profitability and preference are also important constructs in evaluating an idea's value. They predict a product concept's likelihood of eventual market success [99-101]. Taken together, the five evaluation criteria above were thought to sufficiently characterize an idea's value in the context of new product concept generation.

The subjective idea evaluation utilized a nine-point Likert scale (Fig. 3) for each of the five evaluation criteria. For novelty, usefulness and preference, three user representatives, who had more than one year's experience of using automotive HUD systems, performed the subjective ratings. For each idea and each evaluation criterion, the average of the three evaluators' ratings was computed for subsequent data analyses. The Pearson's correlation analysis was conducted to measure interrater reliability between the three evaluators [102]. As for the profitability and technical feasibility criteria, two industry domain experts, who each had over ten years of work experience in the automotive industry, conducted the subjective ratings. These domain experts had relevant expertise in the design of Advanced Driver Assistance Systems (ADAS) in general and the automotive AR HUD system design in particular. For each idea, the two experts individually performed subjective ratings, and, then, the differences were resolved through discussion to reach a consensus. Since the two experts were in fields of complementary areas to each other, H/W and S/W, respectively, they assessed the technical feasibility and profitability of the idea through technical/commercial discussions rather than simply using the average of their respective scores.

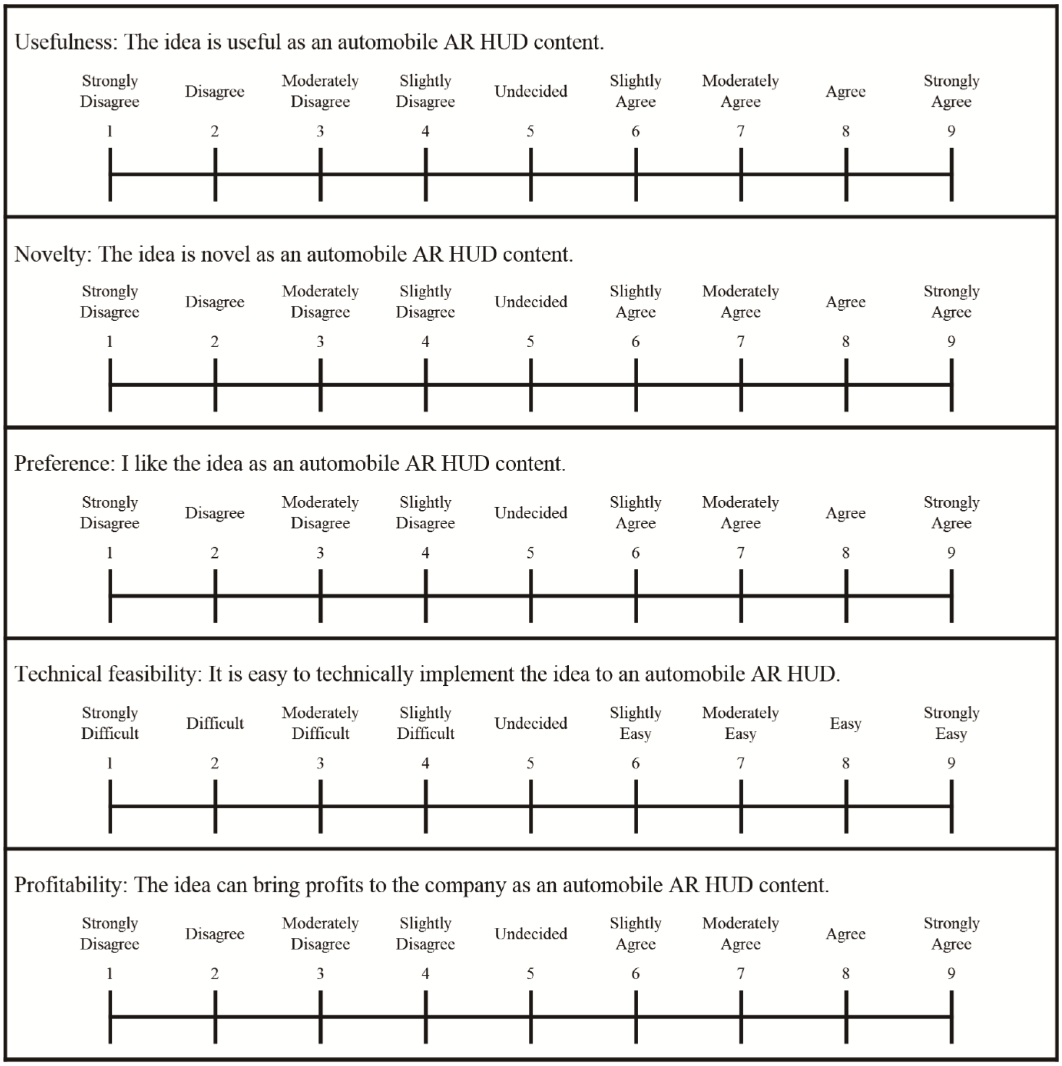


Figure 3: The nine-point Likert scales used for idea evaluation

In order to evaluate the utility of TeRPODs as brainstorming stimuli for technology-push new product concept generation, the two participant groups were compared using the idea evaluation data. The following hypotheses were tested using the idea evaluation data:

- H1: The mean idea novelty rating is higher for the TeRPODs group than for the control group,
- H2: The mean idea usefulness rating is higher for the TeRPODs group than for the control group,
- H3: The mean idea technical feasibility rating is higher for the TeRPODs group than for the control group,
- H4: The mean idea preference rating is higher for the TeRPODs group than for the control group, and
- H5: The mean idea profitability rating is higher for the TeRPODs group than for the control group.

Because the evaluation measures (dependent variables) may have correlation with each other, we conducted a multivariate analysis of variance (MANOVA) to explore both the multivariate effect and univariate effects of the ideation group (independent variable). First, Spearman's correlation coefficients between each pair of the five idea evaluation criteria were computed for the testing of the hypothesis of MANOVA. Then, MANOVA was performed considering the results of the correlation analyses.

This study also employed a fixation score to evaluate the effect of using the TeRPODs on the severity of design fixation [67, 103]. The formula for the fixation score is provided in Equation (1) [79]. The fixation score is computed by dividing the number of 'repeated ideas' by the total number of generated ideas. The numerator in Equation (1), "total number of repeated ideas," refers to the number of ideas grouped into an idea bin with at least one other idea. Being in a bin with other ideas means that ideas with similar functions were derived from other ideators as well. The fixation score was calculated for each participant and a t-test was conducted to compare the two participant groups in the mean fixation score.

$$\text{Fixation} = \frac{Total\ number\ of\ repeated\ ideas}{Total\ number\ of\ generated\ ideas} \qquad (1)$$

Two additional metrics were employed to measure how many 'good' ideas were generated by each participant group. They were: the good ideas count and the good ideas proportion. A 'good' idea was defined as an idea with a high usefulness score, and, simultaneously, a high novelty score [92, 96]. For each participant group, the good ideas count was determined by counting the number of distinct ideas whose novelty and usefulness ratings both exceeded a predetermined threshold – in the current study, the threshold was set at five on the nine-point rating scale shown in Fig. 3. The good ideas proportion was determined by dividing the number of good ideas count by the total number of distinct ideas. A chi-square test was conducted to statistically compare the two participant groups in the good ideas proportion.

4.3 Results

The set of all ideas resulting from the idea data pre-processing revealed that the control group generated 288 ideas (on average, 19.20 ideas per participant) and the TeRPODs group, 317 ideas (on average, 21.13 ideas per participant). Some examples of the generated ideas are provided in Table 3. By eliminating repeated ideas within each group, we found that the control and TeRPODs groups generated 162 and 185 distinct ideas, respectively. The similarity grouping of ideas within each participant group further identified 85 and 89 idea bins for the control and TeRPODs groups, respectively.

Table 3: Example ideas generated from the ideation experiment

No.	Idea description	Group
1	Install a virtual guardrail on the side of the road for safety	TeRPODs
2	Provide real estate information in passing areas	TeRPODs
3	Create virtual objects for driving exercises and licensing tests	TeRPODs
4	Indicate the height of the speed bump	Control
5	Mark the parking position within the parking lot	Control

6	Indicate potential customers for taxis	Control

The Pearson's correlation analyses performed for the interrater reliability between the three evaluators are shown in Table 4. The Correlation coefficients of all nine pairs (three pairs of evaluators for the three evaluation measures) showed at least moderate relationship (r > 0.5) [104].

Table 4: Pearson's correlation analysis for the three user representatives

	Usefulness			Novelty			Preference		
	A	B	C	A	B	C	A	B	C
A	1			1			1		
B	0.50**	1		0.58**	1		0.53**	1	
C	0.57**	0.62**	1	0.57**	0.52**	1	0.56**	0.57**	1

Note. A, B, and C represented each evaluator; * = $p < 0.05$; ** = $p < 0.01$

The Spearman's correlation analyses performed for the ten pairs of the five idea evaluation metrics (novelty, usefulness, technical feasibility, preference and profitability) are shown in Table 5. All pairs except the usefulness-technical feasibility and preference-technical feasibility had a significant correlation, but among them, three pairs (the usefulness-preference, r = 0.81; profitability-technical feasibility, r = 0.52; and novelty-technical feasibility, r = -0.31) showed a clear (greater than weak) correlation that the absolute value of coefficient was greater than 0.3 [105].

Table 5: Spearman's correlation analysis for idea evaluation metrics

	Usefulness	Novelty	Profitability	Preference	Technical Feasibility
Usefulness	1				
Novelty	0.10*	1			
Profitability	0.19**	-0.10*	1		
Preference	0.81**	0.15**	0.17**	1	
Technical Feasibility	0.07	-0.31**	0.52**	0.04	1

Note. * = $p < 0.05$; ** = $p < 0.01$

Due to the high correlation between the usefulness and preference rating scores (Spearman correlation coefficient = 0.81), the preference score was excluded from the subsequent MANOVA test – correlations among the dependent variables of

MANOVA must not be strong (Bray and Maxwell, 1985). Thus, the MANOVA test was conducted for the other four evaluation metrics. Shapiro-Wilk, Levene's and Box's M tests all indicated that the idea evaluation data met the assumptions of MANOVA (p-value > 0.10 came from all tests). The preference rating score data was analysed separately by an analysis of variance (ANOVA).

The MANOVA result indicated that the two participant groups significantly differed in the mean idea evaluation score vector consisting of the usefulness, novelty, technical feasibility and profitability rating scores (Wilks' Lambda $= 0.34$, $F_{4,25} = 12.26$, p-value < 0.01). Tukey's HSD tests performed for each of the four rating scores further indicated that the mean scores of usefulness, novelty and profitability ratings differed significantly between the two participant groups (p-value < 0.05); however, the technical feasibility rating score did not show such significant between-group difference. The ANOVA test performed for the preference rating score found a statistically significant group mean difference ($F_{1,28} = 5.38$, p-value $= 0.03$). The results of the univariate tests and the ANOVA test for the preference rating score are provided in Table 6. Overall, the TeRPODs group performed significantly better than the control group, in terms of the mean values of the usefulness, novelty, profitability and preference measures.

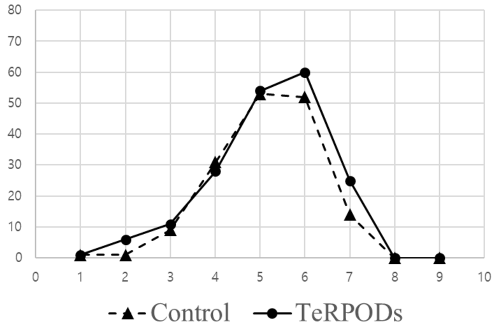
Table 6: The means and standard deviations of idea scores for five criteria

Group	Usefulness	Novelty	Preference	Profitability	Technical Feasibility
TeRPODs	6.05 (0.70)	5.74 (0.49)	5.83 (0.78)	4.31 (0.53)	3.58 (0.54)
Control	5.37 (0.85)	5.23 (0.40)	5.22 (0.63)	3.77 (0.47)	4.02 (0.83)
Mean Difference	0.68*	0.51**	0.61*	0.54**	-0.44

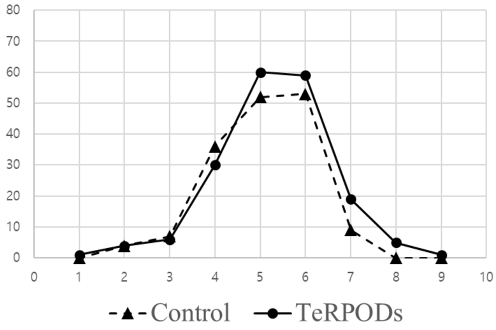
Note. Standard deviations are in parentheses; * = $p < 0.05$; ** = $p < 0.01$

The average fixation score of the TeRPODs group showed 0.75 and that of the control group showed 0.76. Shapiro-Wilk test and Levene's test all indicated that fixation score data met the assumptions of t-test (p-value $>$ 0.10 came from both tests). The result of the t-test conducted to test the mean difference between the two participant groups in the severity of design fixation did not show any statistically significant between-group difference, $t(28) = -0.97$, p-value $= 0.34$.

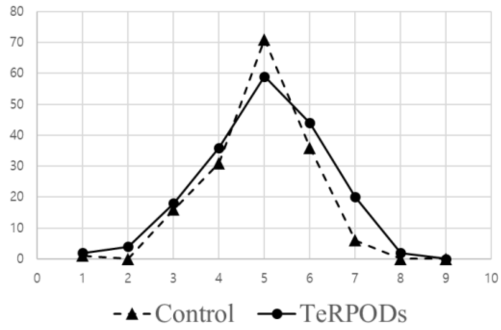
Analysis of the distribution of evaluation scores was performed. The frequency distributions for each evaluation measure are shown in Fig. 4. For usefulness, novelty, and preference, for easy visualization, the decimal point of the evaluation score was calculated as abandoned values and shown on the plot. For example, there were 60 ideas with usefulness scores greater than or equal to six and less than seven. These ideas were presented as six points in Fig. 4(a). In all evaluation measures, ideas with score of 5 or more (positively evaluated) were derived more from the TeRPODs group. In profitability and technical feasibility (Figs. 4(d) and 4(e)), ideas with less than 5 points (negatively evaluated) were derived more from the TeRPODs group.



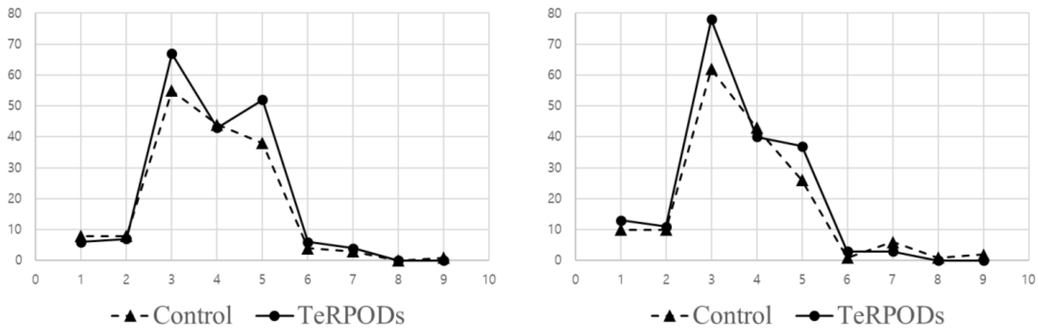
(a) The frequency distribution of usefulness score



(b) The frequency distribution of novelty score



(c) The frequency distribution of preference score



(d) The frequency distribution of profitability score

(e) The frequency distribution of technical feasibility score

Figure 4: Frequency Distributions for the score of five evaluation measures

A heat map analysis was performed to visually represent the ideation outcomes for each participant group and the difference between the two groups (Fig. 5 and Fig. 6). As shown in Fig. 5, the heat map created for each participant group provided an immediate visual summary of the distribution of ideas in the usefulness-novelty (U-N) solution space. Each of the axes spanning the U-N solution space was divided into 8 intervals in accordance with the nine-point Likert scales used, and, thus, a total of 64 cells were created. For each cell within the U-N solution spaces in Figs. 5(a) and (b), the number of distinct ideas within it was counted and the cell was shaded proportionally – the maximum count was 8 and was shaded with the darkest black color. The total number of distinct ideas placed in each quadrant was noted in the corner of the quadrant. The heat maps (Figs. 5(a) and (b)) revealed that: 45 out of 89 distinct ideas (50.56%) produced by the TeRPODs group resided in the first quadrant of the U-N solution space and were "good ideas" with both the usefulness and novelty scores greater than or equal to 5; on the other hand, only 27 out of 65 distinct ideas (41.54%) generated by the control group were good ideas. The TeRPODs group generated good ideas at a higher proportion than the control group, $\chi2$ (1) = 28.41, $p < 0.01$. Good ideas and improvement-needed ideas from each group are listed in the appendix.

In addition to the U-N solution space of each group, The difference in the distribution of distinct ideas in the usefulness-novelty (U-N) and the technical feasibility-profitability (TF-P) solution spaces between the two groups is presented as the heat map in Fig. 6(a) and 6(b), respectively. For each cell of the U-N solution space in Fig. 6, the difference in the number of distinct ideas between the two groups within it was calculated by subtracting the number of distinct ideas in the control group from that in the TeRPODs group. The cell was also shaded proportionally – the maximum of the absolute value of the difference was 9 and was shaded with the darkest black color if the TeRPODs group generated 9 more distinct ideas. On the other hand, it was evenly dotted if the Control group generated more distinct ideas. The more the Control group generated distinct ideas, the greater the density of the dots. Fig. 6(a) shows that (1) novel but not useful ideas were generated more from the TeRPODs group than the control group (Quadrant 2) as novel and useful ideas (Quadrant 1), (2) "best of the best" ideas (ideas that were distributed in the upper right area of Quadrant 1, the space of good ideas) were generated more from the TeRPODs group than the control group, and (3) the improvement-needed ideas that were neither novel nor useful (both usefulness and novelty ratings less than 5 on the nine-point Likert scale) were generated less from the TeRPODs group than the control group (Quadrant 3). Fig. 6(b) shows that the TeRPODs group produced more profitable (both technical feasible and not) ideas than the control group.

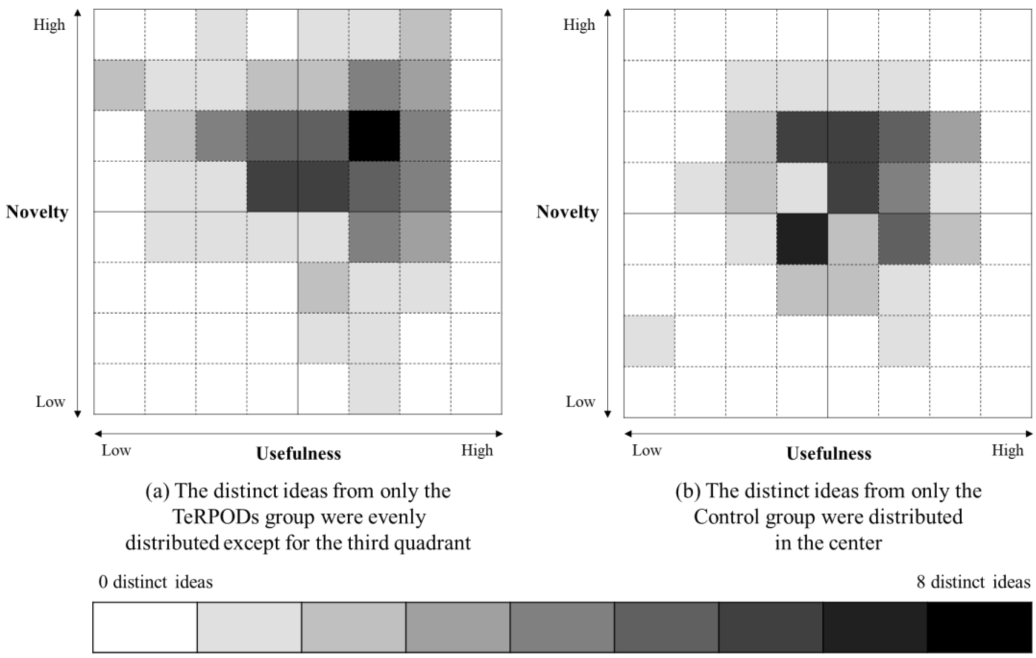


Figure 5: Usefulness-Novelty (U-N) heat map of the two groups

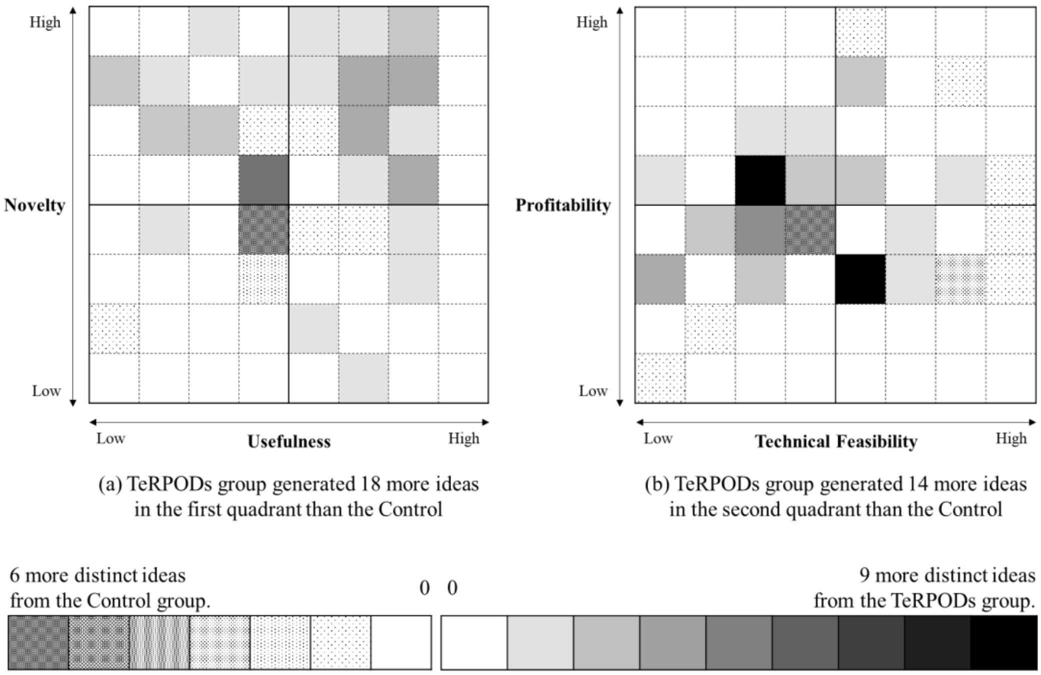


Figure 6: The difference in the distributions of distinct ideas between the two groups in usefulness-novelty (U-N) and technical feasibility-profitability (TF-P) spaces

Chapter 5

Discussion

This study presented a novel ideation aid termed TeRPODs for supporting technology-push product concept generation. A technology-push product concept generation problem is specified in terms of a new technology and a domain of application (the target domain) for which the new technology is to be utilized to create novel products/applications. TeRPODs referred to example applications of the technology collected from domains other than the target domain. A procedure for preparing and utilizing TeRPODs was developed. Our hypothesis was that the use of TeRPODs as brainstorming stimuli would significantly improve the outcome of technology-push product concept generation.

An experiment was conducted to empirically evaluate the utility of TeRPODs. The technology-push product concept generation problem considered was that of developing new automotive AR HUD applications. Two groups of participants (ideators), one utilizing a relevant set of TeRPODs (the TeRPODs group) and the other (the control group) without any ideation aids, performed individual brainstorming to generate new automotive AR HUD application concepts. The two groups were compared with each other in terms of usefulness, novelty, preference, profitability, and technical feasibility. As idea evaluators, a group of user representatives subjectively evaluated the generated ideas in usefulness, novelty and preference; also, domain experts subjectively evaluated the ideas in profitability and technical feasibility. The two participant groups were also compared in the measures of quantity (the number of all ideas and that of distinct ideas), diversity (the number of idea bins) and severity of design fixation, and the number and proportion of good ideas (both usefulness and novelty ratings greater than or equal to 5 on the nine-point Likert scale).

The experiment results indicated that overall, the TeRPODs group produced a significantly better ideation outcome than the control group – the use of TeRPODs significantly increased subjective usefulness, novelty, preference and profitability ratings – it is worth noting that the utility of TeRPODs was supported by the evaluations of both the user representatives (usefulness, novelty and preference) and the domain experts (profitability). The TeRPODs, however, did not improve technical feasibility of generated ideas.

It was found that the TeRPODs group generated more good ideas at a higher proportion and less improvement-needed ideas (neither novel nor useful; see Quadrant 3 of the U-N solution space in Fig. 5) at a lower proportion than the control group. These observations are thought to strongly support TeRPODs as a useful ideation aid because the end outcome of an ideation activity is typically the high-value ideas carefully selected from the generated alternatives on the basis of multiple evaluation criteria [107].

It is thought that the positive effects of TeRPODs on ideation outcomes are attributable largely to their intrinsic characteristics: the TeRPODs effects on the quantity (the set of all ideas and the set of distinct ideas) and diversity (the number of idea bins) of ideation outcomes could be accounted for on the grounds that the TeRPODs were by definition technologically related to the given concept generation problem and the TeRPODs set was constructed to cover a wide variety of applications of the technology. Technological relatedness would help ideators easily relate TeRPODs to the concept generation problem at hand. The availability of various example applications (comprehensiveness) would facilitate exploring the concept space globally in a time-efficient manner.

The effect of the TeRPODs on the usefulness of ideation outcome may be attributed to the usefulness of the TeRPODs themselves – they were chosen among commercially available/successful products. A commercially available/successful TeRPOD would, explicitly or inexplicitly, contain information or know-hows as to how it created customer values. In utilizing a TeRPOD as a source of inspiration for technology-push product concept generation, such information/know-hows may be reflected in the generated product concepts.

The TeRPODs effect on idea usefulness may also be interpreted in light of the finding of Kristensson and Magnusson [108] that ideators must have a contextual use experience of a technology to generate ideas for its applications. When addressing a technology-push product concept generation problem, an ideator, due to the problem's very nature, likely has little or no prior experience of using the technology in the product domain under consideration or any other domains. In such situation, the TeRPODs could provide the ideator with an opportunity to indirectly experience utilizing the technology in various contexts, through mental simulations; while the experience is indirect and also pertains to different or distant product domains, it would still help the ideator gain an understanding of the technology and its potential within certain specific contexts. In fact, the domain experts, who have evaluated ideas, said that the function or context of the ideas generated from the TeRPODs group was more specific. That is, it would be possible to say that the use of TeRPODs makes ideators think more concretely about how to use the technology.

As for the positive TeRPODs effect on the novelty of ideation outcome, the domain difference between the TeRPODs and the technology-push concept generation problem is thought to be the major contributing factor. During technology-push product concept generation, TeRPODs would in many cases function as sources of analogies. The domain difference requires an ideator to perform cross-domain analogical reasoning, which is, making connections between concepts drawn from disparate areas. Cross-domain analogical reasoning is known to be associated with abstract [109, 110] and creative thinking [60, 111-112]. Earlier studies showed that distant analogies could increase the novelty of ideas [49. 60-62, 113-114].

Taken together, the TeRPODs effects on usefulness and novelty could be interpreted that TeRPODs can improve creativity of product concept generation. Usefulness and novelty are generally considered as two defining characteristics of creativity [91-95]. Fig. 6 shows that the TeRPODs group has more good ideas at a higher proportion, which are evaluated as both useful and novel, than the control group (the distinct ideas of the TeRPODs group were distributed more in the upper right corner of the U-N heat map, the area that good ideas were placed).

The positive effect of the TeRPODs on the preference rating appears to be a corollary of that on idea usefulness. The two criteria were found to be highly correlated ($r = 0.81$). The user representatives that conducted ideation evaluation seem to have regarded the two evaluation criteria as similar constructs.

It was found that novelty significantly correlated with preference ($r = 0.15$). This was in line with multiple previous studies that product creativity is positively correlated with product preference [101, 115-116] and creativity is defined as requiring both usefulness and novelty [91-95]. However, the degree of correlation with preference was much lower than usefulness ($0.15 < 0.81$). Perhaps, the way usefulness and novelty are related to user preference depends on the problem context. In the context of automotive driver information systems, novelty may not be as important as usefulness as a correlate of user preference – in the particular context of driving, the users (drivers) would consider an application's practical usefulness in supporting the driver tasks and improving driving safety as a more relevant factor than its novelty. In other contexts, however, novelty might be as important as or more important than usefulness [117].

As for the TeRPODs effect on profitability, it is not clear what aspects or characteristics of TeRPODs gave rise to the effect. Profitability showed just weak correlations with usefulness ($r = 0.19$), novelty ($r = -0.10$), and preference ($r = 0.17$). Thus, as a construct, profitability evaluated by the domain experts seems fundamentally different from the three idea evaluation criteria. On the other hand, profitability had a moderate positive correlation with technical feasibility ($r = 0.52$). This suggests that the domain experts considered technical feasibility as a factor influencing profitability.

The TeRPODs were found to have no significant effect on the technical feasibility of ideation outcome. This is thought to be the consequence of the domain difference between the TeRPODs used and the target domain of the technology-push concept generation problem – the TeRPODs were found from distant product domains, that is, those of smartphones and smart glasses; the technology-push concept generation problem was concerned with automotive AR HUD applications. Although adopting the same AR technologies, the smartphone and smart glasses domains substantially differ from the automotive domain in the way AR is physically realized and also in terms of the design constraints. For example, automotive AR HUD applications should be safely utilized while driving, and, this safety requirement limits the range of functions the technology can provide; but this constraint in general does not necessarily apply to AR applications in other product domains, such as smartphones or smart glasses. Thus, many ideas originating from non-automotive sectors may be infeasible in the automotive context.

It needs to be pointed out that the lack of significant TeRPODs effect on technical feasibility does not represent an entirely undesirable outcome concerning the utility of TeRPODs. To be able to think freely and generate novel ideas, an ideator should not be affected too much by existing technical or non-technical constraints during ideation [108]. In fact, a moderate negative correlation was found between the technical feasibility and novelty rating scores ($r = -0.31$) confirming an inherent trade-off between the two.

Relatedly, it is perhaps worth noting that 14 not technically feasible but profitable distinct ideas were generated more from the TeRPODs group than the control group (see Quadrant 2 of the TF-P solution space in Fig. 6(b)). This was the largest of the between-group differences found in the four quadrants of the TF-P space heat map. This observation could be interpreted that the use of TeRPODs promotes generating ideas that are currently not technically feasible but nonetheless have potential to bring profits in the future if technological advances make them feasible.

The use of TeRPODs was found to not increase the severity of design fixation - the mean fixation scores of the two participant groups did not significantly differ. This was despite the fact that the TeRPODs utilized in this study (Fig. 2 and Table 2) provided detailed descriptions of example products including visual images. Such detailed information is known to act as mental barriers and cause design fixation [108]. The lack of increase in the severity of design fixation may be because: 1) the TeRPODs were from distant domains and provided only indirect contextual use experiences, and, therefore, could not be immediately related to the design problem and its context, 2) the TeRPODs represented diverse examples. Related to the latter, previous studies have reported that the exposure to various design knowledge improved the variety of ideation outcomes and reduced the fixation effect [12, 67, 87, 118], and 3) the TeRPODs provides ideators with knowledge of the principles of new technology and how to apply it, by giving examples of new technology being applied. This is thought to have addressed the possible fixations due to a lack of understanding of the new technology [119]. The opinions of the ideators who used the TeRPODs support this argument. They commented that a large amount of hints presented by the TeRPODs made it easy to create various ideas. It also said that it was easy to generate ideas by simply following the process of analogical thinking (transferring).

Overall, the experiment results support our research hypothesis that TeRPODs would enhance the outcomes of technology-push product concept generation when utilized as brainstorming stimuli. TeRPODs are expected to serve as a useful tool for supporting technology-push inventions. As discussed above, the utility of TeRPODs is thought to result from their inherent characteristics, that is, technological relatedness, comprehensiveness (a wide coverage of different applications of the technology), usefulness, provision of contextual experience, indirectness of contextual experience and domain difference.

The observed utility of TeRPODs may be further interpreted in light of previous research findings on analogy-based ideation. Specifically, the observed utility of TeRPODs may be interpreted as providing an additional support to the importance of analogical distance. In analogy-based ideation, an analogy's utility is known to be affected by its analogical distance to the ideation problem [49, 60-62, 113-114]. Analogical distance should be not too close, not too far but adequate for best ideation outcome [120]. The farther the analogical distance, the higher the novelty of the idea but the lower the quality of the idea [121]. Among the characteristics of

TeRPODs mentioned earlier, technological relatedness and provision of contextual experience appear to be qualities of close analogies; on the other hand, domain difference and indirectness of experience, those of far analogies. Mixed together, these near and far analogy characteristics may place TeRPODs at an analogical distance beneficial to ideation performance. Perhaps, the construct of 'analogical distance' could be decomposed to a few sub-dimensions corresponding to the four characteristics of TeRPODs (the levels of technological relatedness, provision of contextual experience, indirectness of experience and domain difference) and their individual and interaction effects on technology-push product conception generation performance could be examined in future research studies. Note that: in addition to the four dimensions, the levels of TeRPODs' usefulness and comprehensiveness should be separately examined in their effects on ideation performance as they are also thought to be important factors.

Some limitations of the current study are acknowledged here with future research directions: first, in this study, only a single experiment for evaluating the utility of TeRPODs was reported. While the experiment served its purpose, fully establishing the utility of TeRPODs would require more such experiments with different technology-push product concept generation problems. Second, the current procedure for preparing TeRPODs for a given technology-push product concept generation problem requires much human effort (manual internet searches and data processing), and, thus, is costly and time-consuming. In order to utilize TeRPODs in practice, an efficient and effective software tool that automates the generation of a TeRPODs set for a given technology-push product concept generation problem would be needed. Third, the current study considered only the brainstorming technique as a vehicle for utilizing TeRPODs. TeRPODs may be utilized in combination with other ideation methods. Further studies are needed to investigate such possibilities. Fourth, in this study, the utility of TeRPODs was verified only through individual brainstorming. However, since group brainstorming is a much more common approach used in industry, the effectiveness of TeRPODs in group brainstorming also needs to be verified.

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Appendices

Appendix A. Lists of Good ideas and Improvement-needed Ideas only from the TeRPODs group

Good ideas only from the TeRPODs group

1. Propose optimum timing and location of refueling considering fuel economy, price, and path
2. Provide maximum travel distance or location for remaining fuel
3. Provide specific information of rest areas such as location, meal menu, and interior facilities
4. Provide real estate information in passing areas
5. Change the color of surrounding streets
6. Advise caution when driving according to weather conditions (e.g. snow, rain, hail, wind, fog, fine dust, etc.)
7. Adjust the colour and ambience of the windshield to match the outdoor weather
8. Emergency response through video call in case of emergency
9. Real-time relay of sports scores
10. Show parked hours
11. Indicate the probability of slipping when parked on a downhill road
12. Light cut-off for convenience, such as deep sleep

13. Warn passersby in the event of a collision risk
14. Detects objects with a risk of collision in a blind spot
15. Show location of movie theater
16. Display information about the hazards of the car ahead (number of accidents, history of drunk driving, etc.)
17. Show the price of the car ahead
18. Mark if there is a dangerous vehicle when rotating unprotected
19. Carpooling information (exchange of information between cars operating on similar routes at similar times)
20. Create virtual objects for driving exercises and licensing tests
21. Install a virtual guardrail on the side of the road for safety
22. Provide lyrics to the song
23. Book a movie if the movie theater is a destination
24. Provide feedback such as time adjustment after the schedule review
25. Upload posts automatically to SNS
26. Provide virtual tuning images and interior images for surrounding cars
27. Display the relative speed of the rear car when changing lanes
28. Mark the expected route of the surrounding cars to prevent accidents
29. Provide information on the entrance, area, distance, height of surrounding buildings, etc.
30. Provide alarm if caught in a speed control
31. Show No Parking Area
32. Indicate availability of lanes by time zone

33. 3Dimensionalize Road Guidance Letter and Arrow
34. Marked on roads with high risk of collapse or flooding
35. Display the distance left to the traffic lights
36. Instantly notify when caught in a traffic jam.
37. Pre-mark the penalty for violating the signal
38. Control the front door, gas, electricity, etc. of the house.
39. Taking care of pets in conjunction with CCTVs at home (e.g. feeding)
40. Show rear seats in Windshield to take care of children
41. Show remaining space in trunk and possible load weight
42. Provide feedback after detection of driving position
43. Highlight surrounding cars that violate or speed up signals to prevent accidents
44. Zoom in if it is too far away to be seen
45. Indicate trash cans around.

Improvement-needed ideas only from the TeRPODs group

1. Mark the location of the LPG station
2. Provide air bag status information
3. Provide cache slide content (revenue from release of windshield lock screen)

Appendix B. Lists of Good ideas and Improvement-needed Ideas only from the Control group

Good ideas only from the Control group

1. Show time to drive using remaining fuel
2. Show parts that require repair and instructions on how to repair
3. Note on important information
4. Mark the parking position within the parking lot
5. Provide top-view image
6. Calibrate the spread of light
7. Block windshield to separate the exterior and interior of the vehicle.
8. Warn rear hazards on exit (motorcycle approach indication)
9. Provide a warning alarm to apply the brakes in the event of a collision.
10. Indicate distance from the object next to it as it passes through a narrow road.
11. Show speed and path to overtake the car ahead
12. Provide video of passenger seat for conversation with the next person
13. Provide internet surfing screen
14. Highlight destination
15. Display the past and future path of travel
16. Provide the driver with a special sign (home if you go straight, way to work if you turn right)
17. Warn by marking strange moving cars around

18. Provide an alarm in advance when the number of lanes is reduced
19. mark the height of the speed bump
20. Highlight lane when it rains or at night
21. Show heavily congested lanes
22. Guide the minimum speed to pass a traffic signal
23. Indicate which traffic signals should be U-turned
24. Show predicted wait time when entering driving through
25. Indicate potential customers for taxis (e.g. those who are waving their hands)
26. Provide bus drivers with the number of passengers and seating status
27. Show the speed required not to be late for an appointment

Improvement-needed ideas only from the Control group

1. Provide location information for vehicle management, such as vehicle maintenance stations and gas stations
2. Mark the location of the rest area and the distance remaining
3. Display temperature and humidity in vehicle
4. Show nearby cargo and gas cars
5. Pre-mark the type of road ahead
6. Show the time the car was driven
7. Notice to prohibit lane change when entering a tunnel
8. Indicate area of risk of traffic accidents
9. Display highway traffic information
10. Provide driver with welcome messages at start-up and goodbye messages at

turn-off

11. Show the number of cars in action in the world

Appendix C. Lists of Good ideas and Improvement-needed Ideas from both groups

Good ideas from both groups

1. Indicate the location of the adjacent restroom
2. Provide advertisements such as discounts and events around
3. Provide information on tourist attractions in the neighborhood
4. Provide popular store information for surrounding buildings
5. Provide information on the concentration of yellow dust and fine dust
6. Provide video call screen
7. Provide a smartphone display to the windshield
8. Transfer vehicle-to-vehicle messages
9. Transfer messages between vehicle and external person
10. Indicate the availability of parking in non-park spaces
11. Mark the route to the nearest parking lot
12. Show remaining parking spaces for each building
13. Assist parking by providing information on the direction of the steering wheel, distance from the rear vehicle, etc.
14. Show a side mirror screen
15. Show rear camera screen while driving
16. Show the roughness of the road surface
17. Display recommended paths depending on road surface conditions

18. Block only the sun's rays
19. Block the Sunlight and ultraviolet light
20. Block only the sun's rays
21. Block the light from the opposite car
22. Mark a dangerous object, such as a stone, that flies toward a car
23. Indicate objects that are at risk of collision when parked
24. Show virtual view through camera when bad weather conditions do not give us a clear view of the front
25. Show by seeing through corners and buildings
26. Show footage of the inside of a building or the back of a corner.
27. Mark an acquaintance's car
28. Guide for operation of Excel and Brake depending on distance from the vehicle ahead
29. Show distance from side and rear car
30. Show if lane change is possible
31. Zoom in on the desired part
32. Create virtual walls on the crosswalk to ensure compliance with the stop line
33. Adjust the screen to change night to day for night blind patients
34. Watch movies and TV when stopping
35. Provide a music playlist
36. Provide a list of recommendations for selecting songs
37. Provide business document information when stationary
38. Photograph or record a video in front

39. Provide mirror mode (vehicle interior screen)
40. Show Favorite Paths
41. Display popular restaurants around
42. Provide map screen
43. Warning alarm when drowsy driving
44. Measure the driver's fatigue and recommend rest if necessary
45. Provide a warning when driving under the influence of alcohol
46. Show bus only lanes
47. Show unseen sections such as hills, curves, etc.
48. Display traffic signs on the screen
49. Indicate a road path to avoid congestion
50. Show the area where the current accident occurred
51. Show traffic lights on the windshield
52. Advise whether to pass or stop at the traffic lights
53. Show the black box screen.
54. Report to the police after detecting illegally parked or wanted vehicles.
55. Show CCTV footage of the house
56. Provide trunk interior information and loaded items information
57. Recommend method of resting and driving according to heart rate and blood pressure

Improvement-needed ideas from both groups

1. Show fuel economy while driving

국문초록

신기술로부터 새로운 시장이 형성되는 시기에는 해당 기술의 활용도와 이에 대한 사용자의 니즈가 불분명하다. 그렇기 때문에, 성공 가능성이 높은 창의적인 제품 컨셉을 도출하기 어려우며, 이를 기술주도혁신 문제라고 부른다. 본 연구에서는 기술주도혁신 문제를 해결하기 위한 새로운 Ideation 보조도구로서 TeRPODs (Technologically-Related Products from Other Domains)를 개발했다. TeRPODs는 제품 개발의 대상 도메인이 아닌 다른 도메인에서 수집한 기술의 적용 사례들이며, 신제품 컨셉 도출을 위한 Ideation 수행 시 보조도구로 활용된다. TeRPODs의 효용성을 실증적으로 평가하기 위하여 Ideation 실험을 수행했다. 피실험자들을 TeRPODs를 사용하는 TeRPODs 그룹과 아무런 보조도구를 사용하지 않는 Control 그룹으로 나눈 후, 각각 자동차 증강현실 Head-Up Display (AR HUD)의 신제품 컨셉을 도출하도록 했다. 실험 결과, TeRPODs 그룹이 더 많고 다양한 아이디어들을 생성했다. 또한, 아이디어의 유용성, 참신성, 고객 선호도, 그리고 수익 기대성 측면에서 모두 유의하게 더 높은 평가를 받았다. 이를 통해 TeRPODs는 신기술을 활용한 신제품 컨셉의 결정을 도와주는 유용한 Ideation 보조도구라는 것을 확인했다.

주요어: 브레인스토밍, 창의성, 아이디에이션, 신제품 컨셉 도출, 기술주도혁신, 유추적 기법

학번: 2014-22646