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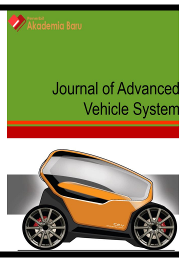

A quantitative evaluation method for identifying essential latent needs and its verification by designing autonomous childcare vehicle

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ABSTRACT

In the product development process, it is important to understand latent needs and reflect them in product functionality, Still, there is a lack of support methods by quantitative analysis to obtain latent needs from consumer needs. In this study, the author proposed, applied, and validated the application of a method to identify important latent needs from a vast amount of needs by eliciting them from the three perspectives of importance, latent-ness, and technological feasibility. The consumers' responses were first translated into interpreted needs and then rated according to a basis of rating for importance, latent-ness, and technological feasibility by ten evaluators. The Degree of Latent Needs (DLN) was calculated by the three metrics. Based on the result for the average and variance of E^{DLN} for each evaluator which is sufficiently small, it indicates that the basis of rating for importance, latent-ness, and technological feasibility in the DLN is effective. The results for the DLN ranking also indicate that the 20 highest DLN points of the interpreted needs contain attractive features in terms of design. On the other hand, we had gotten some pushback on the average of each interpreted need (A^{DLN}) and its variance which indicates opposing opinions among evaluators. As it is possible that attractive needs are hidden and may lead to the discovery of latent needs through individual pinpoint interviews, the interviews with the minority evaluators were conducted. The interview results indicate that the important latent needs with low DLN rates might be able to discover by conducting follow-up interviews such as "The device is able to recognize items (food or not) that a child wants to put in the mouth" and "The device is able to provide human touch and warmth while changing the diaper".

Keywords:
Latent needs, innovative design, product development, prototyping, customer requirement

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1. Introduction
1.1 Latent Needs in Product Design

Today's market has been becoming more than more mature. A new product design is also becoming more than more difficult facing competitive circumstances. It has become more difficult than ever to create hit products that accurately meet customer demands. Under these

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circumstances, product developers and manufacturers have been forced to shift from technology-push to market-pull product development in order to create products with true customer benefits. Market-pull product development is based on the need or requirement for a new product or a solution to a problem, which comes from the market place. The need is identified by potential customers or market research. A product or a range of products is then developed, to solve the original need. Market-pull product development also sometimes starts with potential customers asking for improvements to existing products. Therefore, identifying customer needs is essential in this type of product development.

Customer needs consist of explicit and latent needs. Explicit needs are customers' clear opinions for their problems' solutions and/or impressions to existing products. However, latent needs are those that many customers recognize as important in a final product but do not or cannot articulate in advance (Ulrich et. al, 2015) [1]. The challenge in identifying latent needs is finding the method to elicit from customers' needs. The success of a product or a service is largely dependent on how far the product or the service satisfies customer needs and demands. Therefore, latent needs are particularly critical to product innovation and success.

1.2 Recent Research Works on Latent Needs

Customers' voices, responses, and needs are subjective. Therefore, it is difficult to analyze quantitatively and eliciting latent needs from them. There are ongoing researchers regarding this matter. Jiao *et al* [2] introduced an analytical Kano (A-Kano) model, which was a calculation and categorizing method of customer needs by using the Kano classifier. This method was adapted from the traditional Kano model [3], which has been widely practiced in industries as an effective tool for understanding customer preferences but is not equipped with quantitative assessment. Ohtomi [4][5] classified three kinds of design according to Kano model [3]. One of them is called a delight design that is equivalent to attractive quality in the traditional Kano model. The delight design analysis was performed by measuring the degree of attainment (comfort) and was applied upon designing product sound by using 1DCAE tool. On the other hand, Sakata *et al* [6] introduced a customer satisfaction calculation method that consisted of 3 perspectives of satisfaction, expectation, and significance, and the product functions were classified into eight spaces using a three-dimensional positioning map. Product functions with low expectations were considered as latent needs despite having a low satisfaction level too. However, the functions with high significance were considered as true latent needs. Another quantitative evaluation approach in product development was introduced by Okamoto *et al* [7], who calculated the degree of exploration and exploitation in product design by extracting and analyzing product function from design documents. Failure Mode and Effect Analysis (FMEA) [8] also is one of the renowned quantitative analysis in product design and development. Failure Mode and Effects Analysis (FMEA) is a structured approach for identifying all possible failures in a design, a manufacturing or assembly process, or a product or service. Failures are any errors or defects, especially ones that affect the customer, and can be potential or actual, while effects analysis refers to studying the consequences of those failures. By scoring the severity of the effect, the occurrence and the detection rate of the failure and calculating the risk priority number (RPN), FMEA is able to assist on discovering failure at its earliest possible point in product or process design. We believed that the methods above are able to be applied as assisting tools for product development. Therefore, we assumed that the research on quantitative analysis for identifying latent needs is important.

2. Objective of this Research – Quantification of Importance of Product Function for Identifying Critical Latent Needs

In product design, the designers are needed to select the function and features to be implemented in the products. However, if all the various functions are combined into the product, it will be expensive and/or heavy and will be unchosen by customers. On the other hand, even if the product is based on a latent need but the necessary functions are overlooked, customers might not consider choosing the product. Therefore, it is necessary to evaluate the importance of the product functions including the functions that are based on latent needs. However, the method to evaluate the importance of functions based on latent needs is insufficient. Therefore, this study attempts to a method to quantify the importance of functions based on latent needs.

In this research, to quantitatively evaluate the importance of functions based on latent needs, we first defined the degree/scoring/rating of whether the customer has specifically stated it or is abstractly aware of it) and called it latent-ness. Then to evaluate the importance of product functions based on latent needs we introduced another two perspectives which are importance: whether the function is unnecessary or indispensable; and technological feasibility: whether it is possible or impossible with existing technology, and each index was scored in five levels. Each of all interpreted needs was given scores of each perspective. Then, by adapting the calculation method from Failure Mode Effect Analysis (FMEA) [8], the three perspectives of importance, latent-ness, and technological feasibility is multiplied to indicate that all three perspectives are essential. This proposed method was called Degree of Latent Needs (DLN). The DLN results were then analyzed to ensure that all interpreted needs that we considered as important received high DLN and therefore we can indicate that this method is applicable as a supporting method in identifying critical latent needs.

In our previous research [9], the method in the elicitation of latent needs from customer needs was verified by first applying and executing the 'guideline for writing need statement' method by Ulrich *et. al*, [1] to interpret customers' responses from the interviews into product functions. The list of guidelines is to focus on 'what is the product' not 'how the product work', to be specific as in original responses, to write 'positive' not 'negative' statement, to list the attribute of the product and to avoid using 'must' and 'should' in the statement. Then, the functions of existing products were enlisted based on the functions stated in their product manuals and in patents' claims. The interpreted needs in the interviews were compared with the functions of these existing products to clarify the final latent needs. In this research, the same interpreted needs before the comparison with existing products are used to identify latent needs.

3. Method

3.1 Latent Needs Discovery Using Working Prototype

In this research, an idea to create a product or service that can help people affected by this Covid-19 pandemic was selected as an applied design subject for validation. To collect brief information regarding customer needs, Malaysian people that are also affected by this pandemic were chosen as a target group. The questionnaire to Malaysian people was distributed in online form regardless of their age, occupation, and marital status. Based on the answers in the questionnaire, most of the parents were concerned about the covid-19 virus, the safety of their children and their children's education as the schools and childcare institutions were closed due to the pandemic. Some of the parents needed to work from home while taking care of their children.

In this research, we assumed that by introducing a working prototype and story of the product to the customers, more latent needs are able to be elicited from the customers. This working prototyping will assist in visualizing and developing an idea or verifying a design concept and function. The working prototype was created to provide the consumer with a high-quality channel of information and images about the solution idea of the problem. The working prototype will be used in the slide presentation in the interview.

Based on the results from the customer feedback questionnaires, a working prototype of a device to help and supports housework and childcare, and overcome the problems in childcare that occurred during the covid-19 pandemic was created is shown in Fig 1. The main functions of this prototype were the childcare functions and the disinfection and cleaning functions. The functions covered in childcare functions were remote-monitoring, measurement of body temperature and other vital signs, image recognition for crime prevention and security, and also for entertainment and education. Indoor and small items disinfection functions and cleaning functions were equipped too. Other functions of the prototype were scheduling and monitoring study and bathing time. The running wheel for this prototype is using caterpillar mechanism and is able to move smoothly on uneven surfaces.

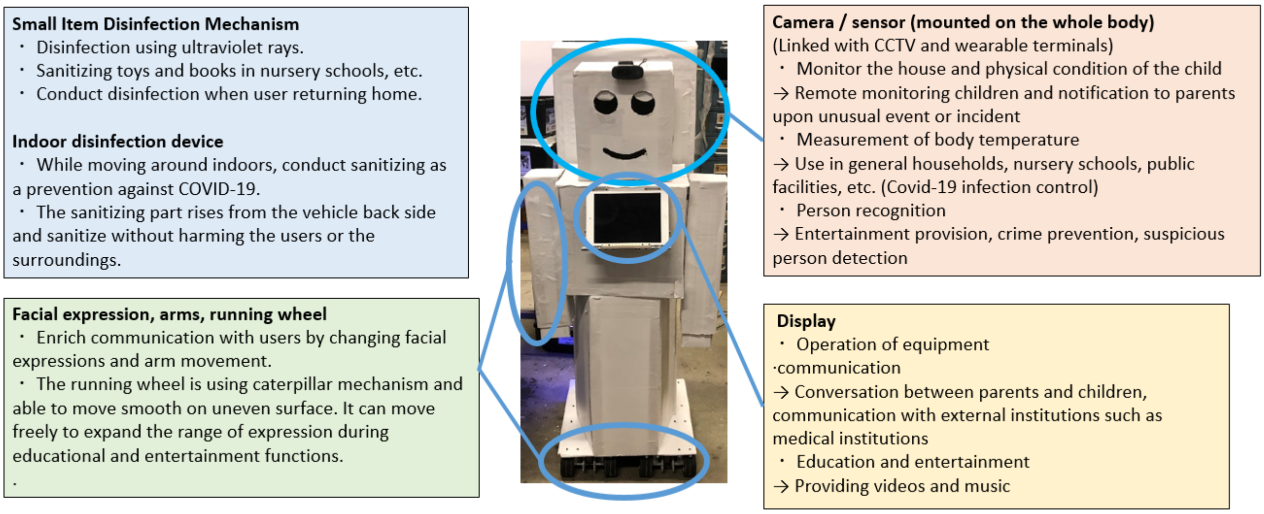

Fig. 1. Working Prototype for Supporting Housework and Childcare

3.2 Needs Interpretation from the Focus Group Interview

A total of 13 parents of different genders and nationalities were selected as focus groups as we assumed that parents are potential customers. They were divided into smaller groups with the same gender, nationality, and occupation to create a more focused group.

In the interview session, slide presentations and interviews were conducted with five different groups of parents. The slide presentation was named `Prototype and Story-based` slide presentation. In the slide, brief information about the latest covid-19 cases and types of virus transmission was introduced. Then, how the pandemic affects the parents were addressed such as school closing or parents needing to work from home. The possible impacts and problems that parents and childcare workers might have in childcare and virus prevention during this pandemic were then explained.

Then, the device sketch and prototype were introduced. The solution concept by using the prototype and story was explained. In the solution concept, how the remote monitoring concept works in helping the parents to monitor their children was explained. Next, the virus sanitizing function such as automatic sanitizer spray or UV light sanitizer box as shown partially in Fig 2 was explained in the story. In the last part, other possible functions that the prototype is able to do were also given such as putting the child to sleep or ventilating the house. The slide presentation was conducted for 30 minutes. In the interview session, interviewees were asked for another 30 minutes of 4 questions about how they will use the device, the good points and bad points about the device, and their opinion about the improvement of the device.

The interview results were then listed and interpreted into the product functions according to the five guidelines by Ulrich et al (2015) [1] which were to focus on 'What' not 'How', to be specific, to create a positive not negative statement, to give attribute to the product and to avoid 'Must' or 'Should'.

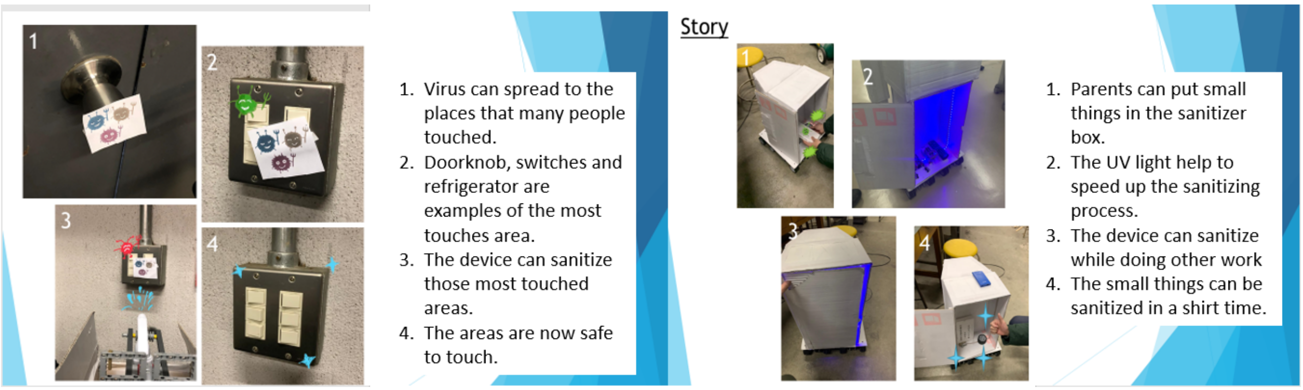

Fig. 2. Illustrated stories of sanitizing functions in the working prototype

3.2 Proposed Quantitative Evaluation Method for Identifying Latent Needs from Product Function

The latent needs of customers are subjective and difficult to evaluate quantitatively. This reason makes the method to quantify latent needs from product function is insufficient today. One of the similar quantitative evaluation methods is Failure Mode Effect Analysis (FMEA) [8] which is a well-known and proven method in the product development process. This paper proposes a method for quantifying latent needs from product functions with reference to the method in FMEA. FMEA concept is to quantify based on three aspects which are severity, occurrence, and detection to measure product failure risk. This paper also set three metrics to measure latent needs from product function. One of the metrics is importance: whether the function is unnecessary or indispensable; which can be compared to the severity in FMEA. Then the technological feasibility: whether it is possible or impossible with existing technology, is recognized as the occurrence in FMEA. The detection aspect in FMEA is then compared to the latent-ness in our paper which we defined as whether the customer has specifically stated it or is abstractly aware of it. Certainly, there are other important aspects in discovering latent needs such as customer satisfaction and expectation, manufacturing cost, ergonomics, and aesthetics, comfortableness that were not applied in this paper as it is assumed that these aspects are similar or included in our three chosen metrics.

In this evaluation method, each metric was scored in five levels, and the basis or rating of each level is described in Table 1, 2, and 3 respectively for each metric. In FMEA, the risk priority number is calculated by multiplying the three metrics in FMEA to assess the risk priority level of a failure cause. In this paper, with reference to the calculation method in FMEA, the degree of latent needs is calculated as follows:

$$\mathrm{V}^{DLN} = I_i \times L_i \times T_i \tag{1}$$

$$\mathrm{E}^{DLN} = \sum_{i=1}^{n} (I_i \times L_i \times T_i)/n \tag{2}$$

where V^{DLN} : A degree of latent need in a product function
E^{DLN} : Average of the degree of latent needs in a design

n : Number of latent needs (product function) in a design
I_i : Importance of a latent needs (product function) in a design
L_i : Latent-ness of a latent needs (product function) in a design
T_i : Technological feasibility of a latent needs (product function) in a design

Ten evaluators used this method to evaluate the degree of latent needs for all the product functions. The average of the degree of latent needs in a product function and its standard deviation was calculated as follow:

$$\mathrm{A}^{DLN} = \sum_{i=1}^{a}(I_i \times L_i \times T_i)/a \quad (3)$$

$$\sigma^{DLN} = \sqrt{\frac{1}{a}\sum_{i=1}^{a}(x_i - A^{DLN})^2} \quad (4)$$

where A^{DLN} : Average of the degree of latent needs in a product function
σ^{DLN} : Standard deviation of the degree of latent needs in a product function
a : Number of evaluators

Table 1
Basis of Rating for Importance of the need in the product design

Basis of Rating	Rate
It is not attractive as the function. The function does not affect the customer's purchasing decision	1
The function might be attractive. The customer might purchase the product because of the function.	2
It is attractive as a function, but the customer might purchase the product even if it does not have a function.	3
If this function is provided, the customer strongly considers purchasing the product.	4
If this function is not provided, the customer will not purchase the product.	5

Table 2
Basis of Rating for Latent-ness

Basis of Rating	Rate
Customers are able to specifically articulate the need for functions by themselves.	1
Customers are unable to specifically state the need for functions by themselves, but they can articulate some fraction of the function concretely in an abstract manner.	2
Customers are unable to specifically state the necessity of the function by themselves, but they can state it abstractly.	3
Customers have the needs of the function but do not clearly recognize it. They can only state it very abstractly not specifically by themselves.	4
Customers are suspected to have the need for the function, but they do not recognize and are unable to state it at all	5

Table 3
Basis of Rating for Technological Feasibility

Basis of Rating	Rate
It does not exist as an established technology such as a patent, paper, or product and is not under research and development. There is no projection of a specific number of years for it to be available	1

It does not exist as an established technology, but it is under research and development. However, it is on the academic roadmap or the specific number of years it will be available is unknown	2
It does not exist as an established technology, but it is on the academic roadmap or expected to be available for a specific number of years	3
It is not feasible at the present time but can be developed by using existing technologies	4
It can be achieved by combining existing technologies at the present time	5

4. Results

4.1 Interpreted Needs from Prototype and Story Based Interview

The Prototype and Story-based slide presentations and interviews were conducted to the 13 parents in 5 different groups. The raw data from Prototype and Story-based slide presentations and interviews which are the answers to the interview questions were interpreted according to the 5 guidelines by Ulrich *et al* [1]. From the interpretation process, 141 interpreted needs were obtained. The raw data for Prototype and Story-based slide presentations and interviews and the interpretations of the needs were partially shown in Table 4 below.

Table 4
Raw Data and Interpreted Needs from Prototype and Story-Based Slide Presentation and Interview (Group 4)

Question No	Interviewee	Raw Data (Interview Answers)	Interpreted Needs
1	A	- I think the reward function is very good.	- The device is able to give children a treat once they finished their homework, lesson and quizzes
	B	- I think the childcare assistance feature would be great. - If the robot can take care of the child, the parents can do different things.	- The device is able to take care of children when parents need to do other task - The device is able to take care of other house chores when parents is taking care of the children
2	A	– I think the robot would be very useful if my children have to go to school again. – The function of disinfecting small items with ultraviolet rays would be very useful if my children have to go to school again.	– The device is able to give children refreshment after finished class/lesson – The device is able to sanitize bag & books before and after school
	B	– The child can also play with the robot and parents can get away from the children for a while. – I like the play and education function, because now I am doing it myself.	– The device is able to take care of children when parents need to take care of themselves – The device is able to teach and play with children – The device is able to teach with voice and facial expression

		– There are a lot of toys, so it would be nice to have a disinfector for small items.	– The device is able to teach from display – The device is able to sanitize small items
3	A	– Disinfection is done more often by washing hands with soap and water, since neither I nor my children leave the house at present. – I use commercial detergent for floors and table tops. – I also use wet wipes. – I don't have small children at present, so I don't need heartbeat and respiration monitoring functions.	– The device will remind user to wash hand with soap – The device is able to wipe, clean and sanitize table, kitchen counter, shelves, and floor – The function of the device can be customized according to customer preferences or by children age
	B	– I have small child so I need the heartbeat and respiration monitoring functions. –	– The device is able to monitor heartbeat and breath of children
4	A	– I would like to have a function to monitor online classes, not a function to make the robot angry. – I want the robot to make the children focus on the lesson. – Parents don't have to get angry or asking the children to pay attention. – I want the robot that can remind them of the time for the next class, tell them what books they need to prepare, etc. (Parents sometimes get angry when they do not pay attention to the classes) – I have experienced that I don't get angry on one day, but I get angry on the next day. – I want a reminder of time, a reminder of what to prepare, and a reminder of when to get ready. – I need to dress nicely before class because I have to turn on the camera during the online class. – I would like to have a facial expression detection function so	– The device is able to scold and alert users – The device is able to make children focus during online class – The device will alert children if they lost focus during classes/lessons – The device will alert children to look at the screen or open the book or listen to the teacher – The device will remind the schedule for next class – The device will remind to finish homework before next class – The device will remind to prepare for next class – The device will remind to dress properly before class – The device is able to give simple guide to get dress before class – The device is equipped with camera with make-up filter – The device is able to scan and detect user's focus in class – The device is able to detect eye contact and head's tilting and turning angle

		that I can see if my child is concentrating during the class. – Function to detect eye movement and head tilt.	
	B	(no answer)	

In order to validate the evaluation method of the Degree of Latent Needs (DLN), this research prepared in advance a list of interpreted needs that the authors considered important in our findings, as in Table 5. The list was made based on the number of times the needs were mentioned in 2 of the 5 interviews by the parents in all of the interviews. The list will be used to compare with the DLN calculation results.

Table 5
Important Interpreted Needs based on Interview Results

No	Interpreted Needs
1	The device part that touches the child is soft and warm like human skin and made of soft material like silicon
2	The device will stop the child from touching dangerous things (broken glass, open wire, fire, etc.)
3	The device is able to put the child to sleep and wake the child up
4	The device is able to give correct/ precise information to parents and authorities (police, hospital, etc.)
5	The device is able to detect small changes in a child compare to the other day

4.2 Distribution of Degree of Latent Needs Values

The interpretations obtained from the interviews were rated based on 'the basis of rating' in Table 1, 2, and 3 for importance, latent-ness, and technological feasibility of the Degree of Latent Needs (DLN) by 10 evaluators. The needs with the 20 highest and 20 lowest DLN values (V^{DLN}), the average of the Degree of Latent Needs (DLN) in a product function (A^{DLN}) and the standard deviation of the Degree of Latent Needs (DLN) in a product function (σ^{DLN}) are shown in Tables 6 and 7. Then the average of the degree of latent needs in a design, E^{DLN} for each evaluators and its average and standard deviation were calculated and are shown in Table 8. The 20 interpreted needs that obtained A^{DLN} values around the average were shown too in Table 9.

5. Discussion

5.1 Average and Variance of E^{DLN} for Each Evaluator

As shown in Table 8, the standard deviation of E^{DLN} for each evaluator was 6.4 for an average of 34.5, which is sufficiently small by comparing to the DLNs rate at the top of the ranking (above 60 points). However, there were two evaluators whose average exceeded 44.0. Since both of the value is close to +2σ, there is a strong possibility of unexplained by only statistical fluctuations, and it is strongly suspected that there are some right reasons.

We examined the two evaluators and found that they were the only two who had experience in childcare. Since it is natural to assume that the presence or absence of childcare experience has a significant impact on the evaluation, we checked the mean and standard deviation for the eight evaluators excluding these two.

Table 6
The 20 Interpreted Needs with Highest DLN values (V^{DLN}), the average (A^{DLN}) and the standard deviation (σ^{DLN}) of the Degree of Latent Needs (DLN) in a product function

No	Interpreted Needs	A	B	C	D	E	F	G	H	I	J	Average (A^{DLN})	STDEV (σ^{DLN})
1	The device’s texture is soft like silicon	75	100	60	60	45	80	10	40	32	60	56.2	25.80
2	The device will tell parents when to change the diaper	60	64	60	48	36	80	64	32	48	40	53.2	14.97
3	The device is able to make children to study and monitor them	100	100	48	36	45	30	20	60	16	48	50.3	29.41
4	The device will remind parents if they did not look after the children (ex. Looking at the phone)	75	100	36	36	36	40	100	16	16	40	49.5	31.13
5	The device’s hand is able to hold child’s hand until he/she falls asleep	80	80	45	48	24	45	45	36	24	60	48.7	19.75
6	The device is able to pat child while slowing the pace until he/she falls asleep	60	80	45	48	18	45	45	36	48	60	48.5	16.26
7	The device is able to wake the child up	100	100	48	32	30	45	10	30	60	30	48.5	30.24
8	The device is able to alert parents when the baby wake up	80	80	48	36	36	50	16	30	64	40	48.0	21.10
9	The device is able to detect small changes in child compare to other day	80	80	60	32	36	60	12	27	36	40	46.3	22.74
10	The device is able to correct a child sleeping posture	100	100	18	48	12	40	45	27	24	48	46.2	31.02
11	The device is able to give human-like touch	75	75	60	48	60	20	48	24	16	30	45.6	22.10
12	The device’s is able to remind parents and children to communicate to each other	80	80	30	45	24	80	20	32	24	40	45.5	24.94
13	The device’s texture feels like human skin	64	80	60	24	45	16	36	45	24	60	45.4	20.65
14	The device will alert children if they lost focus during classes/lessons	80	80	36	36	48	20	60	45	18	24	44.7	22.71

15	The device is able to monitor baby sleeping	100	80	75	16	36	25	30	25	20	25	43.2	29.98
16	The device's temperature is same as human	45	75	60	30	45	50	16	30	16	60	42.7	19.59
17	The device is able to calm the child	75	100	36	32	36	40	24	24	36	24	42.7	25.02
18	The device is able to give facial expression	48	48	60	36	30	60	60	20	24	40	42.6	15.03
19	The device is able to teach user	80	75	36	32	45	30	10	48	40	30	42.6	21.15
20	The device is able to give a human-like warm hug	80	80	48	36	45	20	48	18	24	24	42.3	22.88

Table 7
The 20 Interpreted Needs with Lowest DLN values (V^{DLN}), the average (A^{DLN}) and the standard deviation (σ^{DLN}) of the Degree of Latent Needs (DLN) in a product function

No	Interpreted Needs	A	B	C	D	E	F	G	H	I	J	Average (A^{DLN})	STDEV (σ^{DLN})
1	The device is able to sweep and vacuum the floor	20	20	15	40	30	10	10	12	30	15	20.2	10.08
2	The device is able to sanitize a lot of books at the same time	15	15	30	40	30	5	5	30	30	20	22.0	11.83
3	The device is able to give right/ precise information to authorities (police, hospital etc.)	24	16	24	36	16	24	20	32	16	15	22.3	7.21
4	The device is able to change the voice tone.	15	30	16	10	9	20	20	30	45	30	22.5	11.18
5	The device is able to purify the air	10	10	40	24	40	25	20	15	20	15	22.9	11.09
6	The device is able to measure body temperature	15	15	30	20	10	25	15	20	60	20	23.0	14.18
7	The device can be turn on and off by the user	15	15	25	25	25	20	5	45	30	25	23.0	10.59
8	The device is able to sanitize house	25	20	30	48	18	20	15	24	20	15	23.5	9.76
9	The device has a power saving mode	5	5	15	20	15	60	20	36	40	20	23.6	17.08
10	The device will remind to measure temperature	10	15	40	30	20	25	15	15	60	10	24.0	15.78

11	The device puts out soap for hand washing	15	15	15	45	10	15	5	45	16	60	24.1	18.63
12	The device is able to scan and recognize people outside /around the house	16	16	32	32	36	25	30	20	20	25	25.2	7.11
13	The device is able to clean up broken glass, spilled water etc.	25	25	40	32	15	50	15	15	20	20	25.7	11.76
14	The device is able to react fast in case of danger	40	40	20	32	24	25	12	20	20	25	25.8	9.05
15	The device is able to sanitize small item in UV box	15	10	30	45	45	30	30	30	9	15	25.9	13.22
16	The device is able to measure temperature (room and body)	20	25	40	20	30	25	20	20	40	20	26.0	8.10
17	The device is able to operate with small power	6	4	15	32	20	60	20	24	60	20	26.1	19.62
18	The device can be set to use when needed only	15	15	20	25	32	30	30	30	45	20	26.2	9.19
19	The device price is affordable	20	20	24	15	25	75	25	16	20	25	26.5	17.43
20	The device will remind the schedule for next class	15	15	30	30	30	30	10	45	30	30	26.5	9.19

Table 8
The average of the degree of latent needs in a design, E^{DLN} for each evaluators and its average and standard deviation

No	Evaluators	A	B	C	D	E	F	G	H	I	J	Average of E^{DLN}	STDEV of E^{DLN}
1	Average of the degree of latent needs in a design (E^{DLN})	44.3	46.5	34.7	36.8	31.1	36.1	23.9	31.3	31.3	29.7	34.6	6.45
2	Variance of the degree of latent needs in a design	591	628	163	131	163	352	216	173	258	198		
3	Standard deviation of the degree of latent needs in a design	24.3	25.1	12.8	11.4	12.8	18.8	14.7	13.2	16.1	14.1		

Table 9
The 20 Interpreted Needs with average DLN values (V^{DLN}), the average (A^{DLN}) and the standard deviation (σ^{DLN}) of the Degree of Latent Needs (DLN) in a product function

No	Interpreted Needs	A	B	C	D	E	F	G	H	I	J	Average (A^{DLN})	STDEV (σ^{DLN})
1	The device is able to correct the position of blanket	80	64	30	48	16	10	30	18	24	36	35.6	22.31
2	The device is able to teach with voice and facial expression	48	64	27	48	36	45	10	15	32	30	35.5	16.33
3	The device will monitor children movement in the house	75	48	40	32	45	25	20	25	25	20	35.5	17.16
4	The device is able to monitor children and notify parent in case of emergency	75	75	20	24	24	50	20	25	15	25	35.3	22.89
5	The device is able to suggest new/suitable game for parents and children	36	48	36	64	15	25	18	36	30	45	35.3	14.63
6	The device is able to sing lullaby to put child to sleep	60	60	12	36	20	30	40	45	4	45	35.2	18.90
7	The device is able to give milk to children only when needed	40	40	48	48	24	20	12	36	60	24	35.2	14.94
8	The device is able to be used in any situation (post-covid19)	20	20	24	48	24	100	32	32	32	20	35.2	24.35
9	The device is able to advice/suggest how to spend free time	45	60	36	36	24	25	9	45	32	40	35.2	13.97
10	The device is able to prevent child from choking	80	80	32	32	24	40	15	0	20	25	34.9	26.09
11	The device is made from strong material	20	15	45	32	30	75	15	30	60	25	34.7	19.74
12	The device will remind to finish homework before next class	60	60	30	30	30	30	30	45	16	15	34.6	15.76
13	The device's size is able to be customized according to child age or user preference	36	48	36	48	45	40	20	18	40	15	34.6	12.48
14	The device's functions are able to be set up only for house chores	30	30	40	20	60	60	20	36	24	20	34.0	15.32
15	The device is able to put child to sleep	60	75	48	24	36	30	15	12	32	8	34.0	21.60

16	The device will stop child from touching dangerous thing (broken glass, open wire, fire etc.)	32	32	50	48	36	50	20	20	20	25	33.3	12.40
17	The device is able to judge the level of sickness and notify parents or authorities (hospital etc.)	75	50	20	48	36	50	20	20	20	25	33.2	20.35
18	The cleaning part of the device is able to be detached.	15	20	30	36	60	20	15	30	75	30	32.9	19.76
19	The device is able to play with children with voice and facial expression	36	60	30	36	36	30	20	9	32	40	32.9	13.20
20	The device is able to recognize items (food or not) that a child wants to put in mouth	80	60	16	20	27	25	25	36	20	20		20.84

The results indicate that the average decreased to 31.8 and the standard deviation was 3.9. By considering the objective of identifying important potential needs, since the DLNs rate at the top of the ranking are above 60 points, the standard deviation from the average and the need for average score adjustment is small enough because it exceeds +7σ. This indicates that the proposed basis of rating in DLN is effective.

5.2 Discussion on DLN rankings

From the results of the 20 highest DLN in Table 6, it indicates that the product functions with the highest DLN on average are indeed attractive features in terms of design and can be assumed to be important latent needs. This suggests that the basis of rating in DLN is effective to assist in discovering essential latent needs. On the other hand, the results of the 20 lowest DLN in Table 7 indicate that the functions with the lowest DLN on average are certainly unattractive as a design feature, and there are many functions that cannot be considered latent needs.

The distribution of the correct answers prepared in advance showed that they were indeed included in the top ranks. For example, the interpreted needs “The device part that touches the child is soft and warm like human skin and made of soft material like silicon”, “The device is able to put the child to sleep and wake the child up” and “The device is able to detect small changes in a child compare to the other day” that was prepared in advance in Table 5 were in the 20 highest DLN (Table 6).

5.3 The Average and Variance of Each Interpreted Need (Product Function)

If the average (A^{DLN}) of each interpreted need is high and the standard deviation is low, it indicates that the interpreted needs (product functions) received consistently high rates from all the evaluators. The high-average and low-deviation characteristics basically mean that the designer can count them as attractive needs in the product design. It also alerts that they have some risks that the high latent-ness is not true latent, but rather explicit, as everyone voted it as important. Therefore, designers should select the product function carefully upon designing.

If both the average (A^{DLN}) and the standard deviation are high, and the minority opinion is genuine, it might mean that “many evaluators think it is important, but in fact, a few evaluators know specific reasons why it should not be considered so important”. This can be interpreted as a dangerous trap to be caught in design. If the average (A^{DLN}) is low but the standard deviation is high, and the minority opinion is genuine, it might mean that "only a few evaluators are aware of what is actually important, while many are not”. This can be interpreted as a great opportunity in design.

Based on the results of the average (A^{DLN}) and the standard deviation (σ^{DLN}) of the Degree of Latent Needs (DLN) in a product function, the rating points where the evaluation is largely divided can be identified. The low average of the degree of latent needs in a product function (A^{DLN}) scores also revealed some ideas that should not be overlooked. The A^{DLN} values for some interpreted needs are around the average of A^{DLN}, but the variance and the standard deviation for each function are large, which means that a small number of evaluators gave high rates to these product functions. For example, as shown in Table 9, the A^{DLN} values for the interpreted needs “The device is able to prevent a child from choking”, “The device is able to judge the level of sickness and notify parents or authorities (hospital, etc.)”, and “The device is able to recognize items (food or not) that a child wants to put in the mouth” are below the average but the standard deviation values are high. A large variance and standard deviation mean that the idea has pushback, indicating that there are opposing opinions to the idea. The interpreted need supported by a small number of evaluators is likely to be important, even if there are objections. It is possible that there are truly attractive needs hidden in the high rates of a minority of evaluators. These may lead to the discovery of further needs through individual pinpoint interviews.

Therefore, we conducted interviews with a minority of evaluators who gave different rates to certain needs. Most of the interview answers indicate that they admit there were mistakes in understanding the interpreted needs (product functions) and giving the rates. However, some of the interview answers show a clear reason of the pushback. For example, the evaluator that rated the need “The device is able to recognize items (food or not) that a child wants to put in the mouth” higher than others explained that the function is essential in a childcare device as there are a lot of death cases of children mistakenly swallowed button battery [10]. After explaining to others evaluators, they also agreed that the function is important for a childcare device. Another example is the need “The device is able to monitor children and notify the parent in case of emergency” which was rated high by one evaluator compared to others. The reason given was that there is a possibility of emergency incidents such as bathtub drownings [11] occurring the moment the parents take their eyes off their children, therefore the function is important for a childcare device. The need “The device is able to provide human touch and warmth while changing the diaper” was also rated high by two evaluators. One evaluator explained that changing the diaper process is a delicate process and it is essential to keep the baby comfortable along the process while the other evaluator clarify that the technology for imitating human touch and warmth is possible to implement. After explaining to others evaluators, they understood the importance of the needs above for a childcare device. There are also needs that are evaluated highly by the majority but low by one or two evaluators. For example, the need “The device’s part can be used and operated separately” was rated low by an evaluator. The reason given was it might be efficient if can separate the parts of the device but the device might not function according to the needs at the time of the incident if the parts are incomplete. After explaining to others evaluators, they also agreed that the function is less important for a childcare device. Based on the interview results, it is indicated that by interview, although the needs were rated low by the majority of evaluators, the importance of those needs was able to be discovered. It clearly indicates that the needs are not recognized by the majority of customers but are indeed essential. This result means that the proposed method surely contributed to identify latent needs that are highly important and not recognized at the interview stage

5.4 Eight Patterns of DLN

The maximum evaluation of DLN is based on the combination/compilation of technological feasibility, latent-ness, and importance to an interpreted need. However, among all the interpreted needs obtained from customers, there are cases of a need with high latent-ness but not high importance, or an important need but still no feasible technology. Therefore, this method also addresses the easy-to-grasp need clustering method according to these three metrics from the viewpoint of practicality which is also possible.

The evaluation points for each indicator were then divided into two levels which are high and low, and classified into eight patterns based on the combination of these two levels. By dividing the needs into these eight patterns as shown in Table 10, it helps to grasp the meaning of each interpreted needs according to each metrics in the future work.

Table 10
Eight pattern of DLN

No	Criteria	Level	Pattern Name & Description
1	Importance	High	**First-come-first-served**
	Latent-ness	High	Most likely to be a valuable latent need, the highest priority if the
	Feasibility	High	evaluation is carefully done and reliable.
2	Importance	High	**Dream**
	Latent-ness	Low	Customer recognize the needs and also they are important,
	Feasibility	Low	although technically difficult
3	Importance	High	**Delight**
	Latent-ness	High	Customers are unable to describe and recognize
	Feasibility	Low	Technically difficult but important
4	Importance	High	**Void**
	Latent-ness	Low	A rare chance of an important and technologically feasible need.
	Feasibility	High	Low latent-ness indicate that the chance is low too which suggest an evaluation mistake.
5	Importance	Low	**Magic Show**
	Latent-ness	High	Customers are unable to describe and recognize the need
	Feasibility	High	Feasible technology but not a necessary function in design
6	Importance	Low	**Fantasy**
	Latent-ness	High	Customers are unable to describe and recognize the need
	Feasibility	Low	Technically difficult and not a necessary function in design
7	Importance	Low	**Needless Care**
	Latent-ness	Low	Feasible technology but not a necessary function in design
	Feasibility	High	Customers are able to recognize the need
8	Importance	Low	**Noise**
	Latent-ness	Low	It is not a necessary function for the design target
	Feasibility	Low	No feasible technology but customers recognize the need

6. Conclusion

The purpose of this research is to verify a quantitative evaluation method for identifying latent needs and verifying it. The quantitative method was developed by rating the interpreted needs of consumers' interview responses based on three perspectives of importance, latent-ness, and technological feasibility. The Degree of Latent Needs (DLN) was calculated by multiplying these three metrics. An interview experiment was conducted by designing and prototyping a childcare vehicle-type robot and interviewing thirteen potential consumers in this paper. Based on the result for the mean and variance of the average of the degree of latent needs in a design (E^{DLN}) for each evaluator which is sufficiently small, it indicates that the basis of rating for importance, latent-ness, and technological feasibility in the DLN is effective. The results for the DLN ranking also indicate that the 20 highest DLN points of the interpreted needs contain attractive features in terms of design. On the other hand, we had gotten some pushback on the average of each interpreted need (A^{DLN}) and its variance which indicates opposing opinions among evaluators. As it is possible that attractive needs are hidden and may lead to the discovery of latent needs through individual pinpoint interviews, the interviews with the minority evaluators were conducted. The interview results indicate that the important latent needs with low DLN rates might be able to be discovered by conducting follow-up interviews such as "The device is able to recognize items (food or not) that a child wants to put in the mouth" and "The device is able to provide human touch and warmth while changing the diaper". The experimental result indicates that the needs which have high-ranked DLN points are essential needs in the product design, and also the standard deviation is small enough to differentiate the important latent needs. In addition, the method can derive the next interview using DLN evaluation results. The next interview can focus on the points at which the latent needs are hidden so that many latent needs can be discovered in the experiment in this paper. In conclusion, the method proposed in this paper surely contributed to identify the latent needs which are not recognized yet but are essential.

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