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A Study on Safety of Environmental Cleaners' Noctilucent Jackets[+]

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Abstract

This research chose 135 environmental cleaners in Busan Metropolitan City as subjects. First, the reality of wearing their safety jackets was investigated. Next, visual evaluation of the reflexive function of the current safety jackets was made. Then, based on the above results and the subsequent improvement proposal, the final product, the research costume, was made.

1. Based on the investigation of the wearing reality of safety jackets and the visual evaluation results of the reflexive function, an improvement proposal was made. As cleaners are usually seen sidewise on the roads and lateral luminosity is rather low, this aspect was compensated on the part of a jacket. Also, the reflexive belt used the diagram of △ to improve visual effects.
2. As the lower body held the accident frequency of 45.0%, the sides of pants had the reflexive belt to increase visibility.
3. In consideration of the mutual effects between the background cloth and general reflexive width, the same width (5cm) of the reflexive belt as that of Type A was adopted.

Key Words : environmental cleaner, noctilucent jackets, safety jacket, reflexive belt

Ⅰ. Introduction

According to the rocketing development into an industrial society and high economic growth, concerns about the safety of working environment have recently risen. As the roles of social members get more diverse, so are those of working clothes.

In particular, among the functions of clothes, the function of protecting body safely from external environment or dangers is now considered momentous. Safe working clothes for injury prevention, such as fire fighters' clothes, are increasingly improving functions.

However, though we see the widespread use of safety jackets for the workers who are exposed to lots of dangers in various working environments, there is no safety standard or criterion about the noctilucent fabric used in safety jackets. In addition, the reflection function

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of the noctilucent cloth material has never been scientifically proved.

Among the precedent researches are the reality of fire fighters' clothes in Korea[1)2)], the revelation of efficient cooling sites for the development of cooling clothes[3)], the development of an umbrella-type sunshade cap[4)5)], working clothes materials centered on the microwave sheltering function[6)], the development of children's clothes by using self-reflexive safety materials[7)], and the reflective characteristics of self-reflexive stuff[8)].

In particular, though we can see active studies concerning fire fighters' garments[9)10)11)12)13)], most researches are concerned with the safety of daytime workers. So, research regarding the safety jackets of nighttime workers has hardly been done. As noctilucent jackets are mostly worn to prevent dangers of nighttime work, their safety needs to be clearly testified.

Therefore, this study is concerned with environmental cleaners, those who wear noctilucent safety jackets and work from sunset to sunrise. With some street cleaners in Busan as subjects, the reality of wearing the jackets is first investigated. Then, after the evaluation of the reflexive function of the present jackets, an experimental garment was made to reflect improved safety.

II. Research Methods

1. Questionnaire about the Wearing Reality of Safety Jackets

1) Subjects

150 questionnaires were distributed to the environmental cleaners in Busan Metropolitan City who have the experience of working at midnight and at dawn. Among them, 135 questionnaires were chosen for the analysis here. After a preliminary inquiry on June 20, 2005 to modify any shortcomings, main examination was held from June 30 through July 9, 2005.

2) Questionnaire Composition

The questionnaire was composed of demographic items and those about the working experience at night and at dawn, working conditions and costume, dangers and actual accidents, and the effects of accident prevention by wearing noctilucent jackets. The subjects were asked to read and choose from multiple choices themselves, but there were a few cases where the researcher read the items for illiterate street cleaners.

2. Visual Evaluation of the Reflexive Function of Safety Jackets

1) Evaluation Date & Place

The evaluation was held at 9 ~ 12 PM on August 20, 2005 at the playground of Dong-A University in Busan, Korea. Though the environmental cleaners in Busan are supposed to work from 5 AM through 5 PM, the time after sunset was chosen for the convenience of experiments. The sunset time then was 19:06:33 according to the Korean Astronomical Academy. So 22:00 ~ 24:00 was selected.

2) Choice of Subjects

Correct visual evaluation requires a person to maintain the same posture for a long time with the safety jacket on. Normal people find it very hard. That's why a mannequin was chosen as shown in Fig. 1.

<Fig. 1> Shape of mannequin
(made by Tokyo Mannequin Co.)

3) Jury Composition

The jury was composed of 10 people in their twenties (M:9, F:1), who had a driver's license, no car accidents, and no serious diseases to affect the experiments directly or indirectly. For normal and optimal visual evaluation, the jury members were asked to have sound sleep, stop drinking one day before the experiments, and drink no caffeine- contained drinks on the day of experiments.

4) Jackets for Evaluation

Provided by Busan's Busanjin-gu and Jung-gu Offices and Yangsan City, the three sets of safety jackets were prepared. Their types are shown in <Table 1>, <Table 2>, and <Fig. 2>.

5) Evaluation Methods

(1) Evaluation Environment Setting

The playground of Dong-A University was selected for the sake of safety even though most working places of the cleaners turned out to be the roadside. <Fig. 3> shows the roads made similar to actual working conditions. The

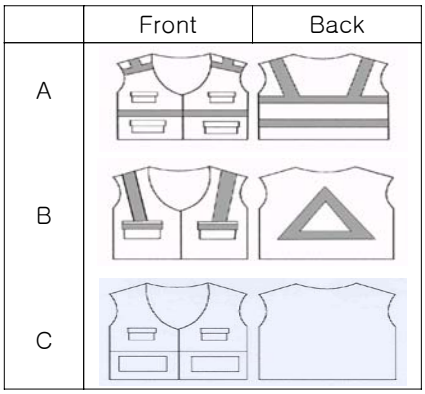
<Table 1> Types of safety jackets and rates of noctilucent belt attachment

Type	Provider	Attachment (Yes/ No)	Attachment area rate (%)	
			Front	Back
A	Busanjin-gu	Yes	16	29
B	Jung-gu	Yes	14	12
C	Yangsan	No	0	0

* A digital planimeter (KP-90, Koizumi, Japan) is used to calculate attachment area rates (noctilucent belt area/ whole area × 100).

<Table 2> Materials of safety jackets

Type	Safety jacket		Noctilucent belt			
	Material rate	Color	Material rate	Reflexive material	Color	Width
A	100% polyester	Fluorescent orange	T/C (polyester 65%, cotton 35%)	Glass bead	Metal silver	0.5㎝
B	100% polyester	Fluorescent orange	T/C (polyester 65%, cotton 35%)	Glass bead	Metal silver	4.5㎝
C	100% polyester	Yellow	-	-	-	-



<Fig. 2> Types of safety jackets

Faculty of Urban Landscape Architecture at Dong-A University set up two one-way lanes (width: 3.25m) according to the lighting standard KS A 3701[15].

(2) Subject Location Setting

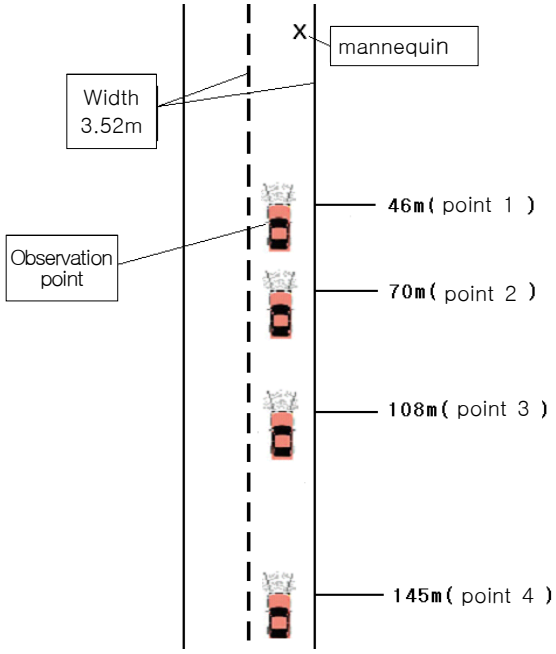
The mannequin serving as the subject was placed at the roadside (See Fig. 3.) near the sidewalk, where real cleaners usually work.

(3) Jury's Observation Conditions & Location Setting

The evaluator took a rest for 10 minutes in a car and, with headlights on, watched the mannequin in a safety jacket for five seconds to remove an afterimage. The observation points were chosen based on the legal speed[16] of 80 ㎞/h and braking distances[17]. The velocity was raised to 100㎞/h, 120㎞/h, and 140㎞/h. The car used here passed the regulations of automobile safety standards and had headlight luminosity as indicated in <Table 3>.

(4) Evaluation Items & Criterion

About the degrees how the three types of the jackets are noticeable, seven-point rating scales were used: point 1 (never seen) ~point 7 (very clearly seen). See <Table 4>.



<Fig. 3> Evaluation environment

<Table 3> The evaluation car's headlight luminosity

Unit: cd*/㎡

	Division	Maximum luminosity per headlight**
Headlight	Left	30000
	Right	30000

* cd: candela
** measuring distance: 292㎝

<Table 4> Evaluation items & criterion

Item	Observation Point	Posture	Evaluation Criterion
How clearly is the jacket seen?	1: 46m	Front/ side/ back	1: never seen 2: hardly seen 3: a little unseen 4: so-so 5: a little seen 6: clearly seen 7: very clearly seen
	2: 70m	Front/ side/ back	
	3: 108m	Front/ side/ back	
	4: 145m	Front/ side/ back	

<Table 5> Material characteristics of the research costume and noctilucent belt

Division	Basic cloth	Reflexive belt
Fabric name	Tricot	Reflexive
Color	Fluorescent orange	Metal silver
Material	Polyester 100%	T/C (polyester 65%, cotton 35%)
Manufacturer	Giolite[18] Inc.	Giolite Inc.
Product No.	GIO-102	9904H
RA or CPL (cd/lux/㎡)	-	14.3
Belt width	-	5㎝
Belt length	-	341.5㎝

(5) Evaluation Procedure

① The evaluation paper was delivered to the jury, the team of evaluators, after explanation about evaluation methods and instructions.

② The degrees of illumination in the evaluation environment were measured.

③ A mannequin wearing a Type-A jacket was put in the given place, while a car with headlights on was placed at Point 1.

④ The mannequin was covered with a black cloth so it could not be seen by the jury who stood in their evaluation points.

⑤ One jury member sat in the driver's seat and took a rest for 10 minutes before experiments.

⑥ The black cloth was removed, and the jury member observed the mannequin's front safety jacket for 5 seconds and wrote down evaluation points. Then the cloth was put on the mannequin again.

⑦ The same procedure was followed for the evaluation of the side and the back.

⑧ When 10 jury members finished their work, Type-B and Type-C jackets were replaced.

⑨ The identical evaluation procedure was held at Points 2, 3 and 4.

3. Making Research Costume

Based on the wearing reality of the established safety jackets and the results of visual evaluation of their reflexive function, the following research costume was made.

1) Materials

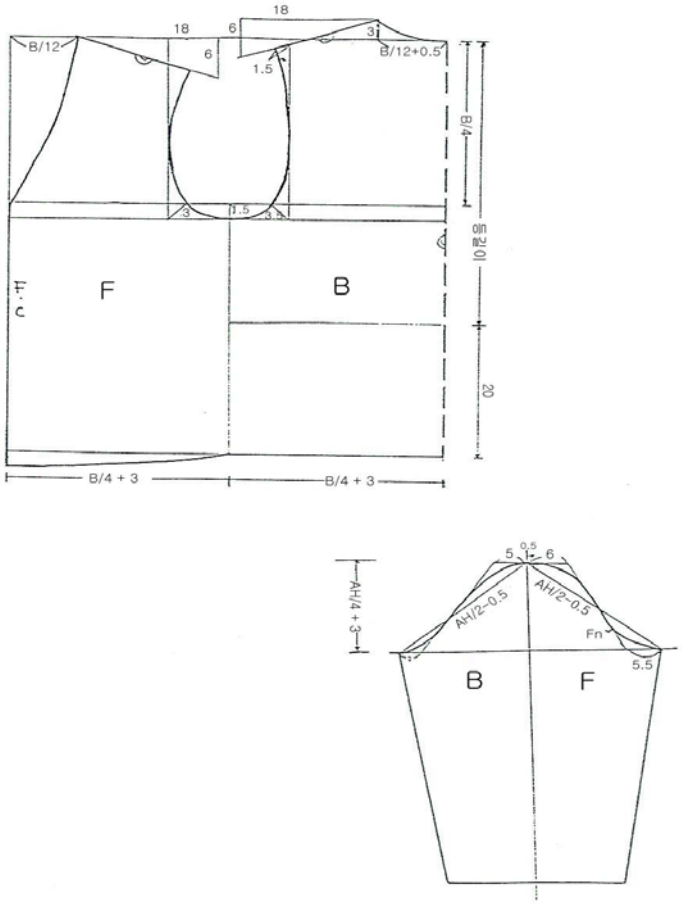
<Table 5> sums up the material characteristics of the research clothes.

2) Measuring and Making Research Costume

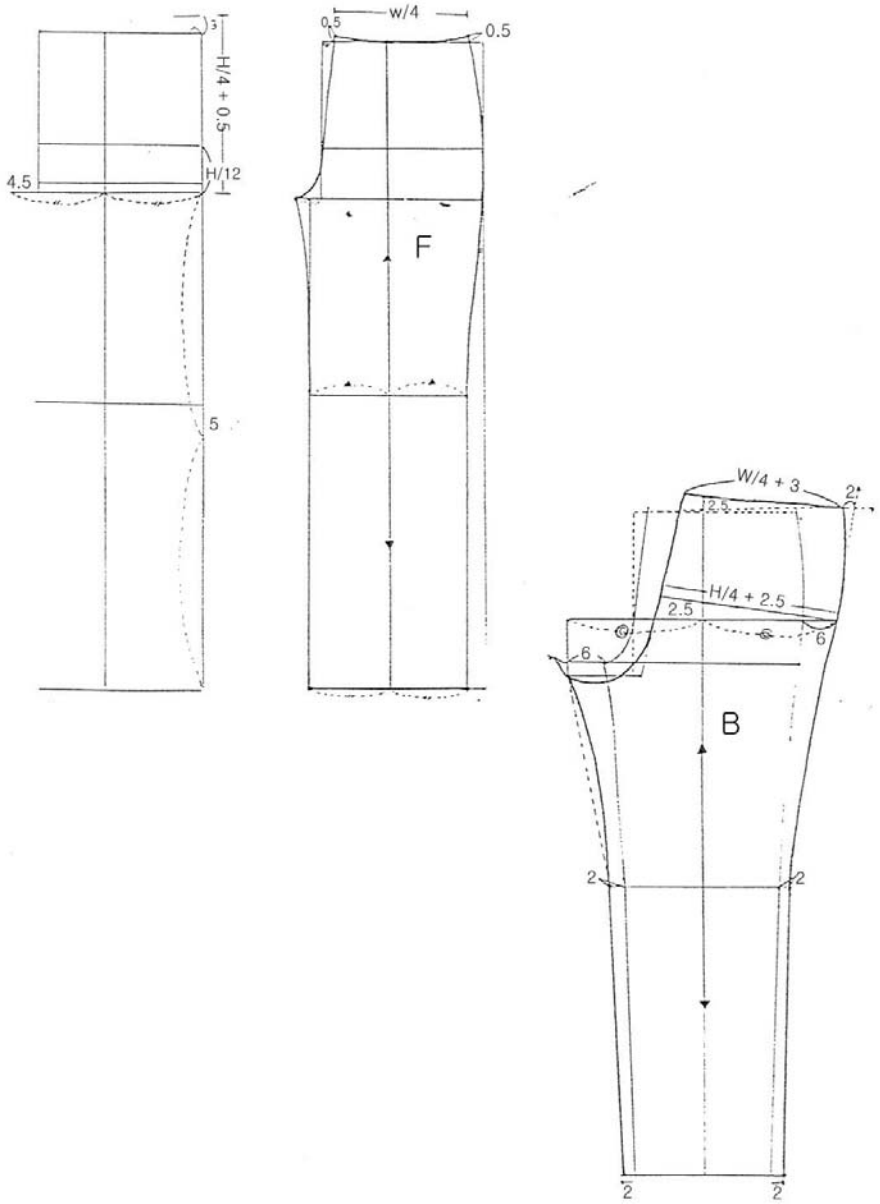
Na Mi-hyang's[19] industrial pattern design items and sizes were utilized in measuring and making the desired research clothes. Confer <Table 6>, <Fig. 4> and <Fig. 5>.

<Table 6> Measurements to make research costume

Parts		Size (㎝)
Girth items	Chest	100
	Waist	82
	Hip	100
Length items	Sleeve	81
	Pants	105
	Hip	18



<Fig. 4> Jacket pattern of research costume



<Fig. 5> Pants pattern of research costume

4. Visual Evaluation of the Reflexive Function of the Research Costume

1) Evaluation Time & Place

The evaluation was made on October 12, 2005. The place was the same as that of the visual evaluation for the current safety jackets.

2) Choice of Subjects & Composition of Evaluators

The choice of subjects and the composition of evaluators were identical to those in the visual evaluation of the reflexive function of the current safety jackets.

3) Evaluation Methods

The same methods as those for the reflexive function of the present noctilucent jackets were adopted.

5. Data Processing

The SPSS/Win (ver 12.0), frequency analysis, dispersion analysis, Duncan's test, and t-test were used for statistical treatment.

III. Results & Discussion

1. Wearing Reality of Safety Jackets

1) Experience, Contents and Costume of Nighttime-Dawn Work

As 98.5% of the survey answerers talked about their experience of nighttime and dawn work, we can see most environmental cleaners are exposed to dangerous working environment. <Table 7> shows the contents and costume of nighttime and dawn work. According to the table, 86.7% are cleaning the roadside and 37.7% are wearing a safety jacket with a reflexive belt on.

2) Recognition of Dangerous Environment and the Accident Prevention Effects of Safety Jackets

<Table 8> summarizes the degrees of recognizing dangers at the time of nighttime and dawn work on the streets and the accident prevention effects of safety jackets. 92.6% felt dangers (a lot: 56.3%, a little: 36.3%) in their working environment, while 62.3% thought safety jackets could prevent accidents.

<Table 7> Contents and costume of nighttime and dawn work

Contents		Frequency (n)	Percent (%)
Work contents	Roadside cleaning	117	86.7
	Garbage collection	13	9.6
	Vehicle driving	0	0.0
	Garbage car collection	2	1.5
	Etc.	3	2.2
	Total	135	100.0
Work costume (multiple answers)	Cap	78	23.5
	Working clothes	46	13.9
	Safety jacket	125	37.7
	Reflexive belt	11	3.3
	Gloves	63	19.0
	Casual clothes	8	2.4
	Etc.	1	0.3
	Total	332	100.0

<Table 8> Recognition of dangerous working environment and the accident prevention effects of safety jackets

Division	Item	Frequency (n)	Percent (%)
Dangers at work	A lot dangerous	76	56.3
	A little dangerous	49	36.3
	So-so	8	5.9
	Not dangerous	1	0.7
	Never dangerous	1	0.7
	Total	135	100.0
Accident prevention effects of safety jackets	Never effective	6	4.4
	Hardly effective	10	7.4
	So-so	35	25.9
	A little effective	48	35.6
	A lot effective	36	26.7
	Total	135	100.0

<Table 9> Direct and indirect experiences of accidents

Contents	Direct		Indirect	
	Frequency (n)	Percent (%)	Frequency (n)	Percent (%)
Had accidents	18	13.3	97	71.9
Almost had accidents	78	57.8	33	24.4
Had no accidents	39	28.9	5	3.7
Total	135	100.0	135	100.0

3) Reality of Nighttime and Dawn Accidents

<Table 9> outlines the nighttime and dawn accidents experienced first-hand or second-hand. Direct experiences amount to 71.1%, while indirect experiences (by colleagues or neighbors) turned out 96.3%.

<Table 10> describes the degrees and physical parts of accidents. As it shows, 68.1% were dead or severely injured, whereas physical parts involved were in the order of legs > trunk > head > arms.

2. Visual Evaluation Results of the Reflexive Function of Safety Jackets

1) Dispersion Analysis Results of the Reflexive Function Following Posture

<Table 11> is a summary of the dispersion analysis results of the reflexive function of safety jackets according to posture. Significant differences were recognized among the types at the level of $p<0.001$ in all kinds of posture. This is thought to have come from the different results of visual evaluation of the types A and B (both attached) and C (no noctilucent belt attached).

According to the average results of visual evaluation depending on posture, the order was back > front > side. In particular, Type B's side had as high points as B's front, maybe because of the special fluorescent diagram of △. In consideration of the cases where drivers see environmental cleaners sidewise, we may need some compensation to heighten lateral luminosity.

<Table 11> Dispersion analysis results of the reflexive function according to safety jacket types and posture

Posture	Type						Total		F-value
	A		B		C				
	M	SD	M	SD	M	SD	M	SD	
Front	3.63a	1.44	3.45a	1.69	1.15b	0.36	2.74	1.72	45.006***
Back	4.75a	1.58	4.50a	1.71	1.15b	0.36	3.47	2.13	87.309***
Side	2.45a	1.11	2.05a	1.29	1.10b	0.30	1.87	1.14	19.500***

***: p<.001

a>b: Groups with significant differences in Duncan's test results

<Table 12> Dispersion analysis results of the reflexive function according to safety jacket types and observation points

Observation points	Type						Total		F-value
	A		B		C				
	M	SD	M	SD	M	SD	M	SD	
Point 1	4.97a	1.25	4.70a	1.82	1.27b	0.45	2.13	2.13	75.535***
Point 2	3.83a	1.44	3.47a	1.72	1.20b	0.41	1.75	1.75	35.297***
Point 3	3.50a	1.48	3.30a	1.62	1.07b	0.25	1.68	1.68	33.620***
Point 4	2.13a	1.50	1.87a	1.04	1.00b	0.00	1.03	1.03	12.565***

***: p<.001

a>b: Groups with significant differences in Duncan's test results

2) Dispersion Analysis Results of the Reflexive Function According to Types and Observation Points

<Table 12> points out the dispersion analysis results of the reflexive function of the safety jackets according to observation points. At every point, there was some significance at the level of p<0.001. The farther it was (from Point 1 to Point 4), values became smaller. Types A and B had less than 4 evaluation points (meaning so-so in terms of visibility) at Point 2 and farther. Type C was worse, showing very low values even at Point 1. In other words, a reflexive belt has a great effect on reflexive function. Therefore, the safety jacket with no fluorescent belt attached is far from safety as it cannot be easily seen by drivers at night.

3. Improvement Proposal & Suggestion of Research Costume

1) Improvement Proposal

Based on the reality of the current safety jackets and the visual evaluation results of their reflexive function, the following improvement proposal was made.

(1) Jacket

As the cleaner's side is usually seen to the driver, the lowest luminosity or visibility of the side should be complemented. That's why a reflexive belt is additionally attached to the sleeve. Getting a hint from the warning form of road signs, △ was utilized on the back of the jacket.

(2) Pants

As the lower body had as high frequency as 45.0% in accidents, enough visibility is demanded. So the side of the pants came to have a noctilucent belt.

(3) Others

As Type A showed the highest values among the three kinds of safety jackets, the same width of the reflexive belt in Type A was adopted in consideration of the best effects between the background cloth and general reflexive width.

2) Suggestion of Research Costume

<Picture 1> shows the research costume made on the basis of the above-mentioned improvement proposal.

4. Visual Evaluation Results of the Reflexive Function of the Research Costume

<Table 13> shows the t-test results of the visual evaluation of the reflexive function between an established safety jacket and the research costume. As the table indicates, irrespective of observation points or distance, every posture contained significant differences at the level of $p \leq 0.001$ or $p \leq 0.01$.

The research clothes held improved visual evaluation results: 6.93 (Point 1), 6.73 (Point 2), 6.0 (Point 3), and 4.60 (Point 4). The average values were 6.01, far higher than Type A (3.61). The research costume's visual evaluation appeared in the order of side/back > front. So it was quite superior to the current safety jackets as far as visibility went.

(Front) (Back) (Side)

<Picture 1> Research costume

<Table 13> Visual evaluation results of the reflexive function between the research costume and the present safety jackets

Location	Type / Posture	Research costume		Present safety jacket A		t-value
		M	SD	M	SD	
Point 1	Front	6.80	0.42	5.00	0.82	6.194***
	Back	7.00	0.00	6.10	0.74	3.857**
	Side	7.00	0.00	3.80	0.92	11.012***
	Total	6.93	0.25	4.97	1.25	8.464***
Point 2	Front	6.40	0.52	4.00	1.05	6.466***
	Back	7.00	0.00	5.10	1.10	5.460***
	Side	6.80	0.42	2.40	0.52	26.944***
	Total	6.73	0.45	3.83	1.44	10.979***
Point 3	Front	5.40	0.52	3.40	1.27	4.243**
	Back	6.20	0.42	4.70	1.49	3.000**
	Side	6.40	0.52	2.40	0.52	15.492***
	Total	6.00	0.64	3.50	1.48	8.070***
Point 4	Front	4.40	1.08	2.10	0.88	4.445**
	Back	4.80	1.03	3.10	1.29	3.431**
	Side	4.60	0.84	1.20	0.42	10.002***
	Total	4.60	0.97	2.13	1.20	8.606***
Total average		6.01	1.11	3.61	1.67	17.689***

**: p<.01
***: p<.001

IV. Conclusions & Suggestions

This research chose 135 environmental cleaners in Busan Metropolitan City as subjects. First, the reality of wearing their safety jackets was investigated. Next, visual evaluation of the reflexive function of the current safety jackets was made. Then, based on the above results and the subsequent improvement proposal, the final product, the research costume, was made.

1. Questionnaire results about the wearing reality of safety jackets

98.5% of the answerers expressed the experience of working at night and at dawn.

37.7% wore safety jackets during nighttime or dawn work. 92.6% were aware of the dangers of nighttime-dawn work, while 62.3% believed in the effects of noctilucent jackets to prevent accidents. 71.1% had direct and 96.3% had indirect experiences of having or almost having accidents during nighttime-dawn work.

2. Visual evaluation results of the reflexive function of safety jackets

According to the dispersion analysis results of the reflexive function depending on posture, every posture contained significance at the level of $p<0.001$. The evaluation results per posture were in the order of back > front > side. The order among the types of safety jackets was Type A > Type B > Type C.

The dispersion analysis results of the reflexive function depending on observation points revealed

some significance at the level of $p<0.001$. Types A and B had low visibility from Point 2 on with evaluation points lower than 4 (so-so). What's worse, Type C with no reflexive belt on showed a very low point even at Point 1. In brief, the attachment of a reflexive belt has a great influence on the reflexive function.

3. Improvement proposal & suggestion of research costume

Based on the investigation of the wearing reality of safety jackets and the visual evaluation results of the reflexive function, an improvement proposal was made. As cleaners are usually seen sidewise on the roads and lateral luminosity is rather low, this aspect was compensated on the part of a jacket. Also, the reflexive belt used the diagram of △ to improve visual effects.

As the lower body held the accident frequency of 45.0%, the sides of pants had the reflexive belt to increase visibility.

In consideration of the mutual effects between the background cloth and general reflexive width, the same width (5cm) of the reflexive belt as that of Type A was adopted.

4. Visual evaluation results of the reflexive function of the research costume

The research costume of a jacket and pants scored 6.01 in visual evaluation results, much better than the established safety jackets.

According to the t-test of the visual evaluation results of the reflexive function between the Type-A jacket and the research clothes, there were significant differences depending on posture and observation points. The reflexive function of the research costume was 6.01, while that of Type A was 3.61. The improved reflexive function was in the order of side/back > front. Thus, with better lateral visibility, the research costume will be even more effective in danger prevention.

In sum, safety jackets show different visual effects according to the attachment shapes and rates of the reflexive belt. In particular, visual recognition sideways is very low. Therefore, an objective criterion of attaching the noctilucent fabric (especially where and how much) is needed. As this study made use of an imaginary environment for the sake of experiments and made only one set of the research costume, a broad interpretation of its conclusions may well be avoided.

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