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On the perceptibility of safety systems

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Abstract

The perceptibility of a safety system is defined as the extent to which the system can be perceived by the senses or the mind. A web-based, pairwise comparison survey, was conducted to evaluate the perceptibility of fifteen safety systems ranging from traffic safety systems to consumer safety. The analytic hierarchy process was applied to estimate the perceptibility levels and rank the safety systems. The results show that protection systems that require activation are more perceptible than passive ones.

Keywords: Traffic safety, Perceptibility, Injury protection systems, Activation

1. Introduction

Road safety systems are designed to reduce the frequency and severity of road traffic collisions. These systems are physically embedded in the users' environment and can therefore affect user behavior. Since this behavior plays an important role in road safety it is important to understand the extent to which users perceive that these systems exist. The objective here is to study which safety systems are more easily perceived by the user and to identify design attributes that affect this level of perception.

The study considers safety systems that provide injury protection in a direct or indirect manner, and early warning systems. *Direct injury protection systems* typically serve as a physical barrier that restricts the damage inflicted to the user in an accident. Examples are helmets and restraint systems such as seat-belts and airbags.

Indirect injury protection systems typically enhance (impair) the users' capability to prevent (cause) an accident, and reduce (increase) its severity. Some systems enhance visibility (e.g., daytime running lights) or the operational control of a vehicle (e.g., electronic stability control), while other systems impair the operational control for an individual (e.g., childproof doors).

Early warning systems are designed to detect and warn the user of imminent danger (e.g., frontal collisions warning systems). *Early warning systems* for transportation activities have only recently emerged, as the required technology was previously unavailable.

Safety systems for non-transportation activities were also studied to see if such systems exhibit comparable levels of perceptibility. These systems also fall under the same categories. For

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example: condoms and sunscreen are *direct injury protection systems*; childproof medication caps and childproof lighters are *indirect injury protection systems*; and smoke detectors are *early warning systems*.

Table 1 below summarizes the fifteen safety systems evaluated in this study: transportation on top and other activities on the bottom. Smoke detectors were the only *early warning system* included in the study since it was felt that the general population is not yet sufficiently familiar with traffic applications of *early warning systems* to provide reliable opinions.

Table 1: Safety systems of the different categories for transportation and non-transportation activities

Direct injury protection systems	Indirect injury protection systems	Early warning systems
Airbags	Anti-lock braking systems	
Bicycle helmets	Daytime running lights	
Motorcycle helmets	Electronic stability control	
Seat-belts	Center high mounted stop lamps	
Side impact improvements		
Condoms	Childproof lighters	Smoke detectors
Sunscreen	Childproof medication caps	
	Lawnmower blade control	

2. The perceptibility survey (available at: www.perceptibility.org)

2.1. Procedure

Perceptibility is defined as the extent to which a safety system can be perceived by the senses or the mind. It was quantified for the fifteen systems in Table 1 with a web-based, pairwise comparison survey. Each survey participant was presented with $\frac{15\times14}{2} = 105$ possible safety system pairs in random order. A screen shot of the user-interface is shown in Figure 1.

Figure 1: A pairwise survey question for structural side impact improvements and motorcycle helmets

For each pair, the participants were asked to indicate, by clicking on a button, whether the protection systems are *equally* perceptible (numerical value=1) or whether one of them is: *slightly* (3), *more* (5), *strongly* (7) or *absolutely* (9) more perceptible. The images and descriptions that were used in the survey for each system are shown in Appendix A.

At the end of the survey the respondents were asked about their demographic characteristics, including: age, gender, occupation, education level, ethnicity, country currently living, native language, and whether or not they had a driver's license[1].

2.2. Implementation

The survey was developed using the Hypertext Preprocessor (PHP) scripting language. The responses were stored in a MySQL database hosted on a secure server.

2.3. Analysis

The responses were analyzed using the analytic hierarchy process in Saaty (1977, 1980). The standardized perceptibility level and the Consistency Ratio (CR) were calculated for each respondent using the eigenvalue method in Saaty (1977). The perceptibility level for each system was calculated by taking the geometric mean of the individual rankings of the respondents, as is generally recommended (Forman and Peniwati 1998), but the results with the arithmetic mean were very similar.

3. Results

The survey was completed by 117 participants and required on average 14.5 minutes. The respondents were 33.8 years old on average, 59.8% were females and 92% had a drivers‘ license. The cultural and social demograophics varied. Distributions for the demographics are provided in Appendix B.

The CR level was used to rank and filter out inconsistent outliers. The amount of filtering was determined from inspection of Figure 2, which shows the mean perceptibility level for each system for different retention percentages. The dashed lines running across the figure are the perceptibility levels for the different safety systems. Note, these levels exhibit only minor deviations when the retention percentage is between 35% and 80%. The 80% level was used for estimation as it is the largest sample size within this stable range. Figure 3 displays the perceptibility levels estimated in this way, including 95% confidence intervals.

[1]This survey has been reviewed and approved by the UC Berkeley committee for protection of human subjects. Protocol number: 2009-10-306

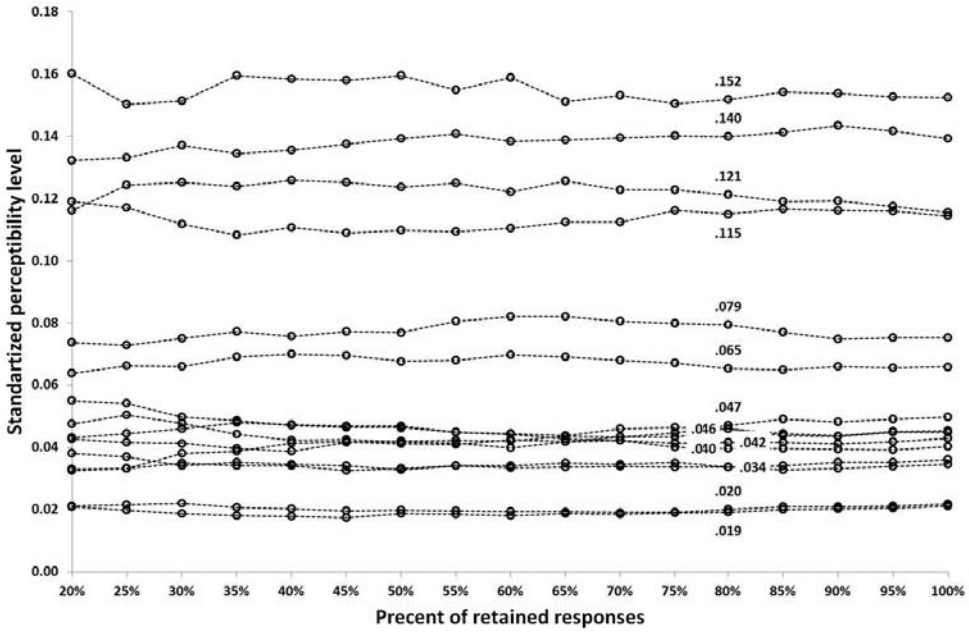

Figure 2: Perceptibility level for different percentages of retained responses

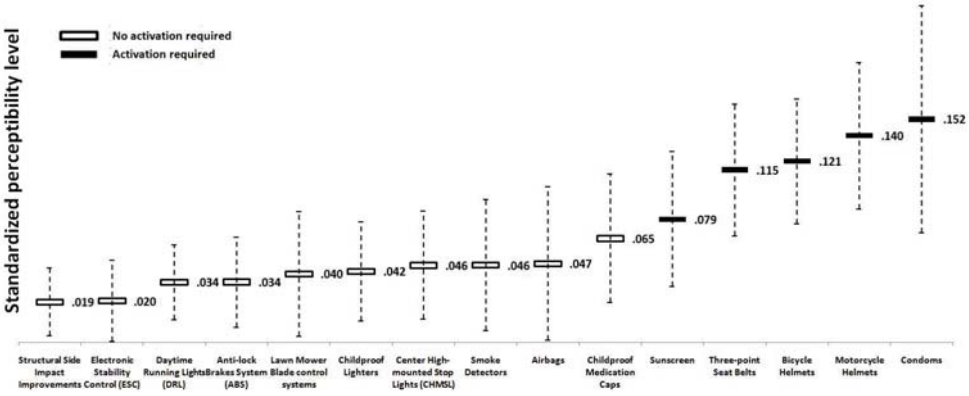

Figure 3: Ordered estimates of the perceptibility level (n = 94)

4. Discussion

The survey revealed that perceptibility was highest for systems that require activation by the user, such as motorcycle helmets. In fact, Figure 3 shows that the five most perceptible systems (and only these systems) require activation. The probability of this grouping is $1/\binom{15}{5} \approx 1/3000$. Thus, a strong association between activation and high perceptibility is likely to exist in reality. This should not be surprising since activating a safety system before every use should increase a users' awareness of the system.

Furthermore, of the five systems that require activation (sunscreen, seat-belts, bicycle helmets, motorcycle helmets and condoms), two are non-transportation systems, which is that same proportion as in the full sample. This suggests that the association between perceptibility and activation holds in general, regardless of the activity.

Acknowledgments

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References

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Appendix A. Descriptions

Frontal airbags are an automatic crash protection system mounted in the steering column or the instrument panel of an automobile. Frontal airbags are designed to inflate in moderate-to-severe frontal collisions and protect the occupant from harmful movements.

Antilock braking systems (ABS) are an electronic braking control mechanism for automobiles that activates under hard braking. ABS is designed to maintain wheel rotation and steering control in situations that would otherwise lock the wheels.

Bicycle helmets are protective headgear designed to provide protection from head injuries in a bicycle collision.

Center High Mounted Stop Lamps (CHMSL) are additional brake lamps located higher than regular stop lamps on the vertical centerline of the rear of an automobile. CHMSL are activated together with regular stop lamps and are designed to reduce reaction time to braking of upstream vehicles.

Condoms are flexible impermeable sleeves worn over a male's penis. Condoms are designed as a contraceptive or as a way to prevent the spread of sexually transmitted diseases like AIDS.

Daytime running lights (DRL) are bright, white forward-facing lights for automobiles that operate in daylight. DRL's are designed to improve automobile conspicuity in the daytime to increase detection by others.

Electronic Stability Control (ESC) are a stability system for automobiles that identifies when the driver is about to lose control. ESC is designed to automatically adjust both braking and engine power to prevent such loss of control.

Motorcycle helmets are protective headgear designed to provide protection from head injuries in a motorcycle collision.

Childproof medication caps are covers of medication containers with an operating mechanism designed to be significantly difficult to open for children under the age of 5.

Childproof lighters are hand-held fire-setting devices with special mechanical features that require acquired handling to generate a flame. Child proof lighters are designed to make operation difficult for children.

Structural side impact improvements are structural modifications of the side beams and the installation of energy absorbing padding of automobiles. These improvements are designed to protect occupants in a side impact collision.

Smoke detectors are warning devices installed in an enclosed space to detect smoke. Smoke detectors are designed to issue an audible and/or visual alarm to warn household occupants of a fire.

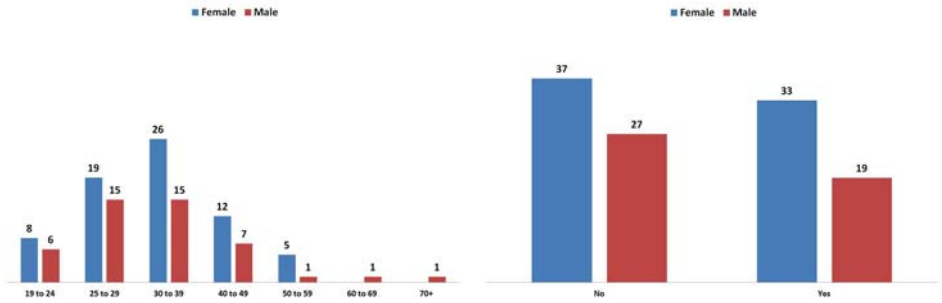
Sunscreens are chemical substances applied on a person's skin. Sunscreens are designed to reflect and absorb ultraviolet radiation from the sun's rays to help protect the skin from damage that may lead to skin cancer.

Lawn mower blade control systems are mechanical levers on walk-behind lawn mowers. They require continuous contact with the lever to rotate the blade and to completely stop rotation within 3.0 seconds of release. Blade control systems are designed to reduce injuries caused by contact with the blades.

Three point seatbelts are a safety harness worn by occupants of an automobile. Seatbelts are designed to secure the occupants in their seats to prevent harmful movements caused by a collision or a sudden stop.

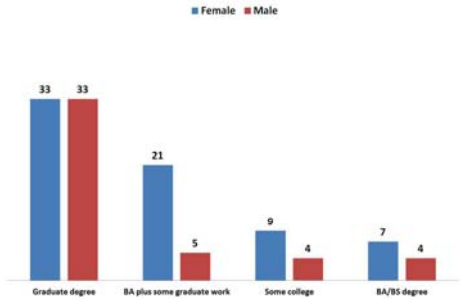
Figure A.4: Descriptions and image of the protection systems of the survey

Appendix B. Demographics

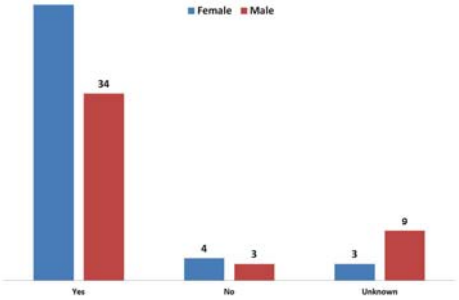


(a) Age

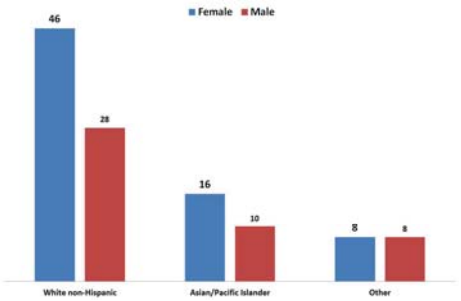
(b) Marital status



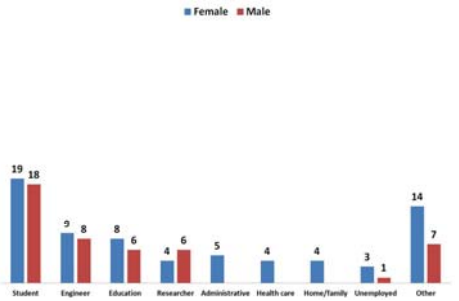
(c) Education level



(d) Drivers' license



(e) Ethnicity



(f) Occupation

Figure B.5: Distribution of respondent demographics by gender