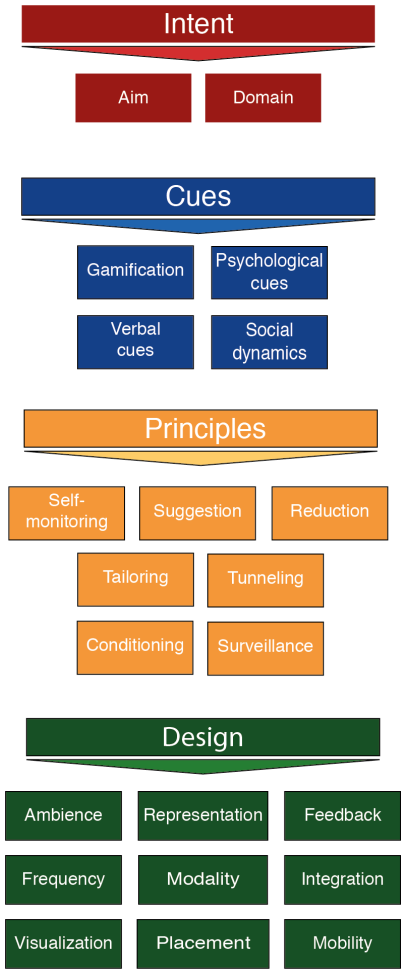

Figure 1: The Persuasion Interface Design in the Automotive context Framework (PIDAF).[13]. Category definitions can be found in Table 3.

Persuading the Driver: A Literature Review to Identify Blind Spots

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ABSTRACT

We present a review of persuasive systems in vehicles based on the Persuasion Interface Design in the Automotive context Framework (PIDAF). It integrates *intents*, *cues*, persuasive *principles* and *design options* for automotive persuasion. Our results show that most systems target safety and eco-driving using conscious cues to alert the driver. Most systems use self-monitoring, tailoring or suggestion as persuasive principles. Visual modalities are still much more popular than auditory or haptic ones. We identified blind spots to support designers and researchers in developing systems addressing areas which are less explored in automotive persuasion.

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KEYWORDS

Automotive; persuasion; behaviour change; literature review.

INTRODUCTION AND METHOD

Persuasive systems for drivers have proliferated in the past decade. For designers and researchers it is difficult to know what has already been tested and with what results, because most reviews focus on behaviour change models which do not look into the specifics of interface design. For example, it is not clear whether visual interfaces have been used in cars more than haptic or auditory ones, and which modality is most effective for driver persuasion. Therefore, there is a need to identify blind-spots in the existing research landscape, both conceptually and from the design point of view. Our contribution fills this gap by looking at persuasive systems in cars. We conducted a literature review of persuasive systems in the automotive domain based on the Persuasion Interface Design in Automotive context Framework (PIDAF) [13] (see Figure 1). The review can be used by researchers and designers to create new systems which tackle less explored strategies or domains. It can also be used to conduct more specific reviews, focusing on one particular aspect or strategy.

A search was conducted in the ACM Digital Library, ScienceDirect (Elsevier), IEEE Xplore and within the journals: Transportation Research Part A, Safety Science and Intelligent Transport Systems. The search was run with AND- and OR- for two types of keyword groups: (1) "car", "vehicle", "driver", "drive"; (2) "persuasion", "persuade", "behavior", "behavior change", "game", "gamification". We only included publications with keywords in their abstract published after 2008. The initial search resulted in 442 hits, which were reduced to 27 based on their relevance. Then a categorization was done according to the PIDAF. Each paper was reviewed individually. Since many categories were not mutually exclusive, we always counted the same paper two or more times. Table 1 provides a detailed description of the results.

RESULTS

Intent. A majority of the publications reviewed targeted driver behaviour, with only one publication addressing driver attitude as well. Approximately a third of the papers were addressing eco-driving, and a majority aimed to increase safety. Only two papers aimed to change other behaviours, outside of these two categories, one of them supporting drivers in learning of functions and another one looking at natural user interfaces.

Cues. Gamification is used in about a third of the papers, where some elements or the entire persuasive system is gamified. Subliminal cues are not abundant in automotive persuasion. Only two papers used them explicitly, once using visual cues to prepare drivers in advance for lane changes and a second time using vibrotactile feedback. More than a third of the papers used verbal cues, either through

PIDAF CATEGORIES

PIDAF includes four levels of decision making in designing for persuasion in cars: intent, cues, principles and design.
Intent includes the subcategories *aim* (attitude or behaviour change) and *domain*: safety, eco-driving and other.
Cues can be *psychological*, *social dynamics*, *gamification* and *verbal*. Psychological cues are either subliminal or unconscious. Social dynamics means a system targets single users, multiple users, uses competition or cooperation. Gamification can be used or not (yes/no). Verbal cues refer to whether a system uses language or not.
Persuasive principles are based on Fogg's taxonomy [9] and include *reduction*, *tunnelling*, *tailoring*, *suggestion*, *self-monitoring*, *surveillance* and *conditioning*.
The **design** considers nine aspects of interface design choices: *ambience* (peripheral or focal), *representation* (concrete or metaphorical), *feedback* (immediate or delayed), *integration* (additional or augmenting), *modality* (visual, haptic or auditory), *visualization* (discrete or continuous), *placement* (inside or outside of the car), *frequency* (in the moment, as a summary or beforehand) and *mobility* (mobile or fixed).

Table 1: Results of the literature review with respect to PIDAF. Explanation of the abbreviations can be found in Table 2.

	Intent		Cues				Principles	Design								
	Aim	*Domain*	*Gamification*	*Psychological cues*	*Verbal cues*	*Social dynamics*	*Persuasion*	*Ambience*	*Representation*	*Feedback*	*Frequency*	*Modality*	*Integration*	*Vizualization*	*Placement*	*Mobility*
Adell, et al. 2008 [1]	B	S	N	C	N	S	SM, SU	F, P	C, M	I	M	V, A, H	Ad,A	D	I	F
Burns et al., 2015 [2]	B	E	N	C	N	S	SM	F	C	I	M	V	Ad	D	I	F
Chin et al. 2017 [3]	A, B	S	N	C	N	M	SM, SR	F	C	D	S	V	Ad	D	I	M
Christiansen et. al 2011 [4]	B	S	N	C	N	S	SM, TA	P	M	I	M	V, A	Ad	C	I	F
Di Lena et al. 2017 [5]	B	E	Y	C	Y	S	SM, SU, CO	F, P	C, M	I	M	V,A	A	D	I	F
Diewald et al. 2012 [6]	B	O	Y	C	N	S	CO, TA	F	C	I,D	M, S	V	Ad, A	D	I	F
Diewald et al. 2015 [7]	B	O	Y	C	Y	S	RE, CO, SU	P	M	D	M, S	V	Ad, A	D	I	M, F
Ecker et al. 2011 [8]	B	E	Y	C	N	CM	SM, TA, SU	P	M	I	M	V	Ad, A	D	I	F
Ibragimova et al. 2015 [10]	B	E	N	C	N	S	SM, CO	P	M	I	M,S	V,H	A	C	I	M, F
Magana et al. 2015 [11]	B	E	Y	C	Y	CM	SM, CO, SU	F, P	C, M	I,D	M,S	V,A	Ad	D	I	M
Pampel et al. 2017 [12]	B	E	N	C	Y	S	SU, TA	F	C	n/a	B	V	Ad	C	O	M
Rakotonirainy et al. 2014 [14]	B	S	Y	C	N	M, CM, CP	SR, TA, CO	F, P	M	I	M	V, H	Ad, A	C	I	M, F
Riener et al. 2014 [16]	B	S	N	S	N	S	TU	F	C	I	M	V	Ad	D	I	F
Riener, 2012 [15]	B	E	N	S	N	S	SU	P	M	I	M	H	A	C	I	F
Rodriguez et al. 2014 [17]	B	S	Y	C	Y	CM	SU, CO, SM	F, P	C	I,D	M, S	V	Ad, A	D	I	M, F
Schroeter et al. 2014 [18]	B	S	Y	C	N	CM	CO, TA	P	M	I	M	V	A	C	I	F
Shi et al. 2012 [19]	B	S	Y	C	Y	CM	CO, SM, TA	F, P	M	I	M, S	V, A	Ad	D, C	I	M
Steinberger et al. 2017 [20]	B	S	N	C	N	S	TU, SM	P	M	I	M	V	Ad	C	I	M
Steinberger et al.2015 [21]	B	S	Y	C	N	S	TU, CO	P	M	I	M	V	Ad	C	I	F
Tanaka et al., 2017 [22]	B	S	N	C	Y	S	TA, SU	P	M	I	M	V, A	Ad, A	C	I	F
Tulusan et al. 2012 [23]	B	E	N	C	Y	S	SM, TA, SU	F	C	I	M,S	V	Ad	D	I	M
van Huysduynen et al. 2016 [24]	B	S	N	C	Y	S	TU, SU, TA	F, P	C, M	I	M	V, H	Ad	C	I	F
Wang et al. 2016 [25]	B	S	N	C	N	M	SR, SM	P	M	I	M, S	V	Ad	C	I	F
Wang et al. 2017 [27]	B	S	N	C	N	S	SU	P	M	I	M	A	Ad	C	I	F
Wang et. al 2015 [26]	B	S	N	C	N	M	SR.	P	M	I	M	V	Ad	C	I	F
Williams et. al 2014 [28]	B	S	N	C	Y	S	RE, SU	F	C, M	I	M	V, A	Ad	C	I	M
You et al., 2012 [29]	B	S	N	C	Y	S	SU, TA	P	M	I	M	V, A	Ad	C	I	M, F

Table 2: Abbreviations for Table 1.

Aim	A = Attitude
	B = Behaviour
Domain	S = Safety
O = Other	E = Eco-driving
Gamification	Y = Yes
	N = No
Psychological cues	C = Conscious
	S = Subliminal
Verbal cues	Y = Yes
	N = No
Social dynamics	S = Single user
	M = Multi-user
CM = Competition	CP = Cooperation
Principles	SM = Self-monitoring
SR = Surveillance	SU = Suggestion
RE = Reduction	TU = Tunnelling
TA = Tailoring	CO = Conditioning
Ambience	F = Focal
	P = Peripheral
Representation	C = Concrete
	M = Metaphorical
Feedback	I = immediate
	D = Delayed
Frequency	M = Momentary
S = Summary	B = Beforehand
Modality	V = Visual
A = Auditory	H = Haptic
Integration	Ad = Additional
	A = Augmenting
Vizualization	D = Discrete
	C = Continuous
Placement	I = Inside
	O = Outside
Mobility	F = Fixed
	M = Mobile

visual text or audio messages. A majority of the publications examined were targeted at single users, namely the drivers themselves. However, four prototypes also considered the communication with other drivers, passengers or social circle. Additionally, 6 papers used competition as a way to change behavior, but only one proposed cooperation between drivers and other traffic participants.

Persuasive Principles. The use of persuasive principles is more diverse and more balanced across the papers reviewed. Most applications made use of self-monitoring tools (13 papers), suggestion (14 papers) and tailoring (11 papers). Conditioning, namely using different types of rewards to incentivize behavior is also more present, with 10 prototypes applying this principle. However, surveillance, reduction and tunneling were less employed. One notable instance of surveillance is engaging the social support group of the driver to observe driver behavior.

Design. A majority of systems reviewed uses visual output modalities, while the prevalence of haptic and auditive modalities is much smaller (6 and 9 papers, respectively). Designers prefer new interfaces, or a combination of new interfaces and augmenting existing ones. Of the latter, we can mention steering wheels, car seat, seat belts and pedals. Additionally, most prototypes make use of abstract designs or a combination of both concrete and abstract. Only 7 papers used concrete designs only. Most interfaces are used inside the car. In only one case persuasion was implemented outside the car, through text messages. A majority is also fixed: displays or other augmented interfaces. Six were nomadic and in five cases, designers used a combination of the two.

DISCUSSION

Any literature mapping involves a process of defining criteria and selection. The landscape of persuasion in the automotive domain is larger than this paper was able to cover, although our endeavor was to include the most relevant publications. Due to space limitations, we will highlight here the most obvious blind-spots. For each decision layer of PIDAF (intent, cues, principles, design) we pinpoint those categories that have been used less in designing systems, based on our review. Firstly,persuasive applications targeting attitude and other domains apart from safety and eco-driving are almost entirely lacking. Secondly, non-conscious cues are not generally used, meaning there is no subliminal preparation for future action. This is an important area for development based on current behavioral research. Additionally, driving is a "solitary activity": most applications target single users. Thirdly, surveillance, reduction and tunnelling could receive more attention in automotive persuasion. Finally, from the design perspective, drivers could be primed more for future actions outside of the vehicle: currently most interfaces are placed inside and are fixed. There is also an opportunity to explore auditive or haptic modalities in addition to visual ones. Designers could explore more delayed, summarized or prior information, in addition to immediate feedback and momentary frequency. There could also be more designs augmenting existing interfaces rather than adding new ones. Persuasive interface

Table 3: Category definitions PIDAF

Aim = type of change desired
Domain = theme the system is focused on
Psychological cues = features guiding future action
Social dynamics = patterns of interaction
Gamification = system use of games
Verbal cues = system use of language
Reduction = narrow down to simple steps
Tunnelling = guide through sequence of actions
Tailoring = provide personalized information
Suggestion = recommend an action
Self-monitoring = inform about self progress
Surveillance = monitor by another party
Conditioning = give reinforcements to shape behavior
Ambience = type of user attention required
Representation = information depiction in interface
Feedback = assessment of user action
Integration = interface assimilation within the vehicle
Modality = system rendering of output
Visualization = way of presenting information
Placement = location of interface
Frequency = recurrence of information
Mobility = movability of the interface

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design is constantly expanding and with this paper we hope to support designers and researchers to further develop work in these underdeveloped areas.

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