University of Toronto
Department of Computer Science

Towards Cooperative Driving - Involving the Driver in an Autonomous Vehicle's Decision Making

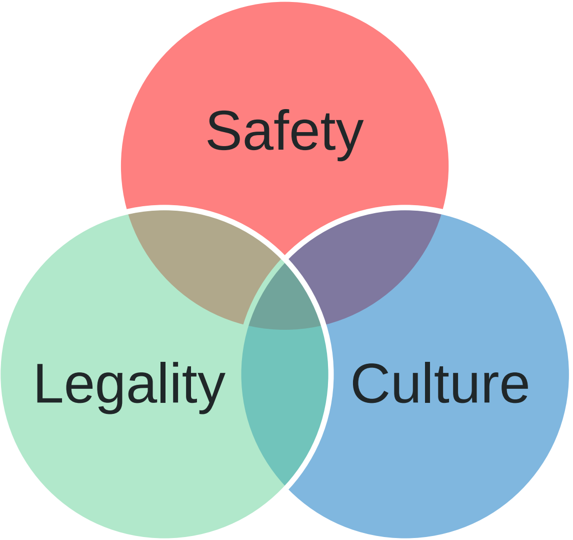
Abdul Kawsar Tushar
tushar21@cs.Toronto.edu

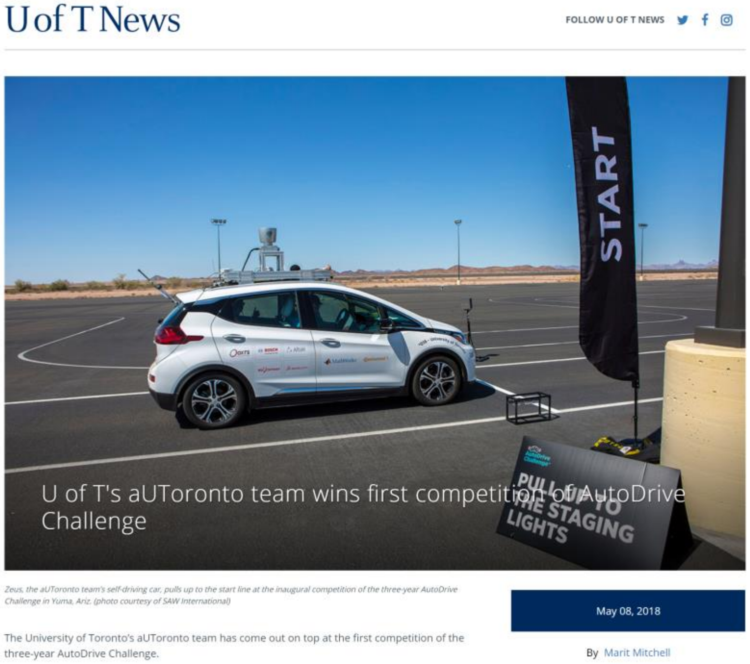
Authors

- Marcel Walch
- Tobias Sieber
- Philipp Hock
- Martin Baumann
- Michael Weber

Institute of Media Informatics,
Institute of Psychology and Education
Ulm University, Germany

Driving Universe and Driving Competition





U of T News

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U of T's aUToronto team wins first competition of AutoDrive Challenge

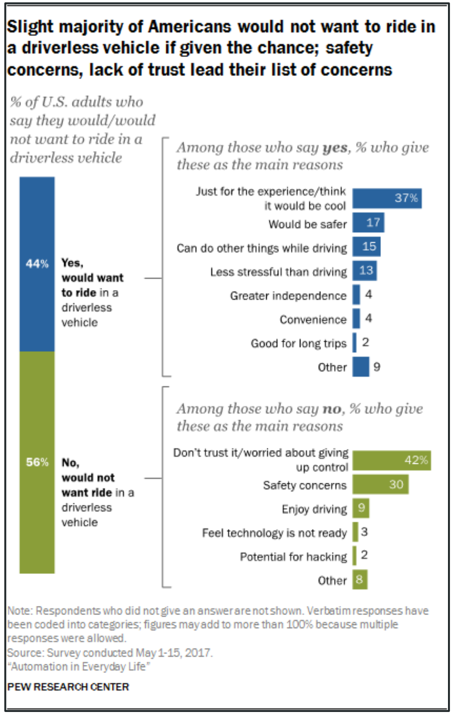
Zeus, the aUToronto team's self-driving car, pulls up to the start line at the inaugural competition of the three-year AutoDrive Challenge in Yuma, Ariz. (photo courtesy of SAW International)

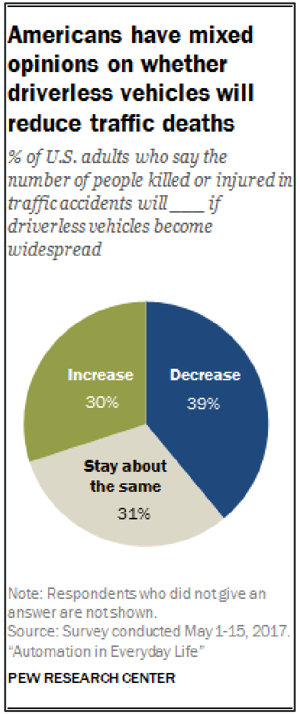
May 08, 2018

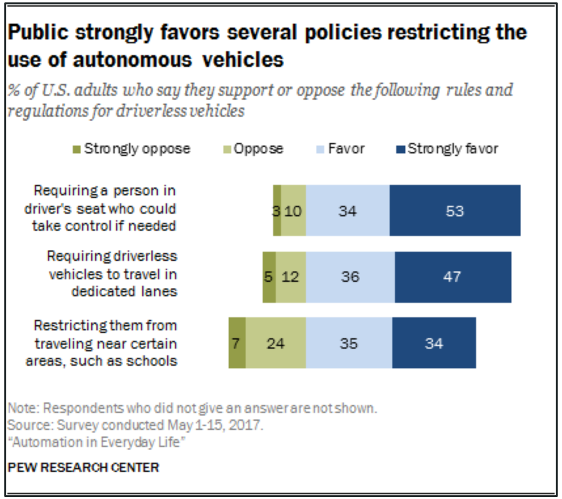
By Marit Mitchell

The University of Toronto's aUToronto team has come out on top at the first competition of the three-year AutoDrive Challenge.

Public Opinion







http://www.pewinternet.org/2017/10/04/americans-attitudes-toward-driverless-vehicles/

Concerns for Acceptance

- “Trust interactions will promote confidence, control, and a sense of safety for the people operating AVs. At the heart of these interactions are four capabilities: **comprehensive sensing, clear communication, response to changes,** and **multiple modes of interaction**.”

Weast, J., et al. "A matter of trust: How smart design can accelerate automated vehicle adoption." White paper by Intel, 2016.

Assistive User Interfaces

Author(s)	Direction	Initiation	Involvement	Completeness	Fallback Capability	Input	Output	Visual Output Position	Haptic Output Position	Temporal Output Mode	Mode Awareness
Mok et al.[41] (AUI '14)	T, H	S	SA	F			S				
Politis et al.[49] (AUI '15)	T, H	S	SA, P	F		P	V, H, S	H	W	O	S, C
Walch et al.[66] (AUI '15)	T	S	SA	F		P	V, A, S	W		S	
Telpaz et al.[58] (AUI '15)	T, H	S	SA, P	F	N		V, A	W		S	
Reimer[50] (AUI '16)	T	U	A	P	S	P	V	D		O	
Dikmen[15] (AUI '16)	T, H	U	A	P		P, T	V				
Van der Meulen et al.[64] (AUI '16)	T	S	SA	F		P	V, A	W		S	
Borojeni et al.[8] (AUI '16)	T, H	U, S	A, SA	F	N	P	V, A	D		O	
Forster et al.[18] (AUI '16)	T	S	SA	F	O	P	V	H		I	S, C
Walch et al.[67] (AUI '16)	T	S	SA	F	O	P, S	V, A, S	C		S	T
Jung Lee et al.[34] (CHI '14)	T, H	U	A	P		T, S	V	C		O	T
Kim et al.[32] (CHI '17)	T	S	SA	P	N	P	V	H, W		S	
Mok et al.[40] (CHI '17)	T, H	U, S	A, P	F	N					O	S, C
Van der Heiden et al.[63] (CHI '17)	T	S	P	F	N	P	A, S			I	
Johns et al.[28] (HRI '16)	T	U, S	A, SA	P	S	P	V, H, S	D	S	S	
Schwalk et al.[55] (PM '15)	T, H	S	SA	F			H		T	S	
Stockert et al.[56] (AHFE '15)	T, H	U	A	F		P	V	H		I	S, C
Melcher et al.[36] (AHFE '15)	T	S	SA, P	F	O	P	V, H, A	D, O	P	S	S
Gold et al.[22] (AHFE '15)	T, H	U, S	A, SA	F		P	V, A	D	P	S	S
Albert et al.[3] (AHFE '15)	H	U	A		S	T	V	D, C, H			S, C, T
Zeeb et al.[71] (AAP '15)	T, H	S	SA	F	N	P	V, A	C		O	C
Zeeb et al.[72] (AAP '16)	T, H	U, S	A, SA, P	F	N	P	V, A	D		O	S, C, T
Petermeijer et al.[46] (AAP '17)	T, H	U, S	A, P	F		P	H		T	S	S, C
Petermeijer et al.[45] (AE '17)	T, H	U, S	A, SA	F	N	P	H, A		T	O	
Van den Beukel et al.[62] (TRF '16)	T	U, S	A, P	F	N	P	V, H, A	D, W	T	S	C
Kerschbaum et al.[29] (IV '15)	T, H	U	A	F	N	P	V, A	D		O	O
Mok et al.[38] (IV '16)	T, H	U, S	A, SA	P		P	V, A			O	S, C
Bueno et al.[9] (ITSC '16)	T	U	A, SA	F		P	V, A			O	
Langlois and Soualmi[33] (ITSC '16)	T	U	A	F	O	P	V, A	H		I	S, C, T
Miller et al.[37] (SMC '14)	T		SA	P		P	V, S	D		S	S, C
Wulf et al.[69] (ITS '15)	T, H	U	A	P		P	V, A	H			S, C
Kim et al.[31] (ITEC '16)	T	U	A	F		P, G	V, H	C	W	O	
Wada et al.[65] (SMC '16)	T	U	A	F	N	P					
Kim et al.[30] (THMS '17)	T	U, S	A, P	F		P	V, A, S	D		S	
Tijerna et al.[59] (TIV '17)	H	S	P	P	N	P	V	H		I	

Table 1. Academic Publications - Results (N=35)

Mirnig, Alexander G., et al. "Control Transition Interfaces in Semiautonomous Vehicles: A Categorization Framework and Literature Analysis." *Proceedings of the 9th International Conference on Automotive User Interfaces and Interactive Vehicular Applications*. ACM, 2017.

Problems with Car Driver Handover

Experimental Setting

Figure 3: The driving simulator in which the study was conducted. The participant is watching a video while automation is activated.

Figure 4: Complex situation: in addition to the broken-down vehicle (simple situation) there is a police car behind it and another car on the side of the opposite lane.

Flow of Decision

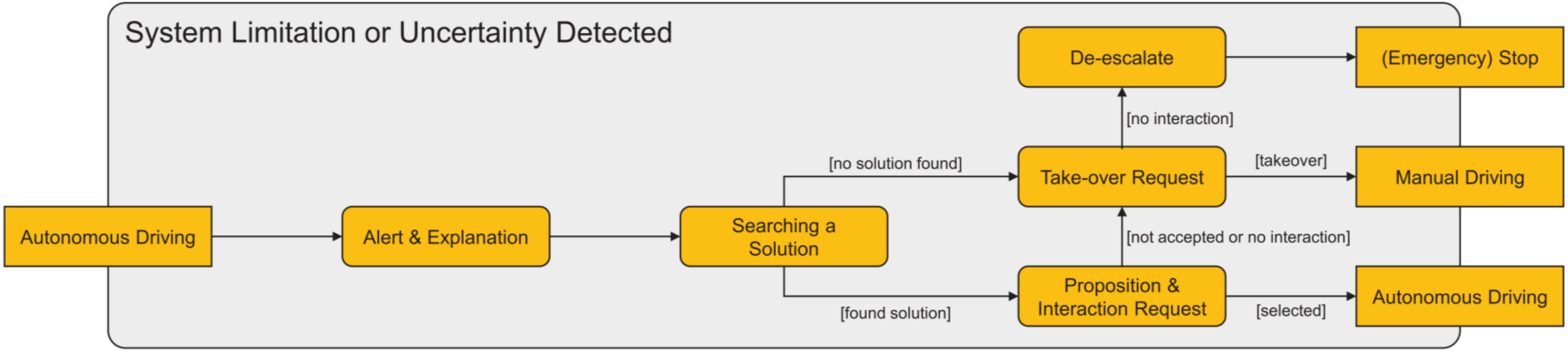
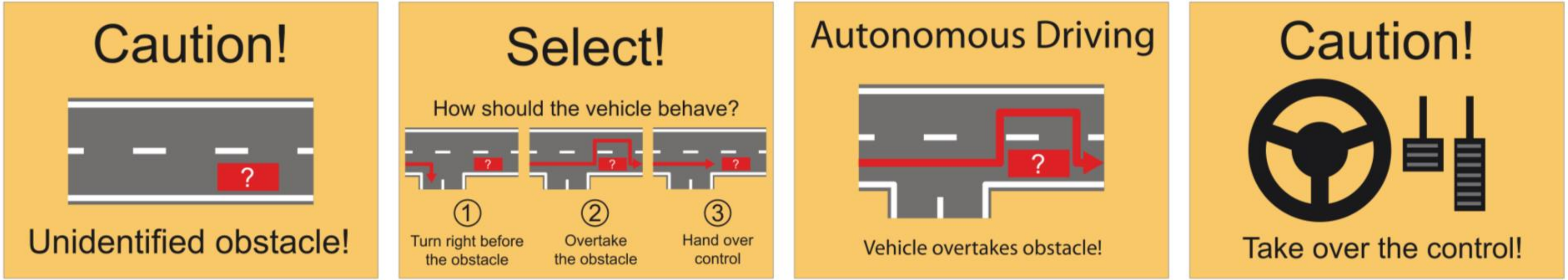


Figure 1: System limitation / uncertainty detected: the system alerts and informs the driver before presenting propositions the driver can choose between to keep automation enabled.

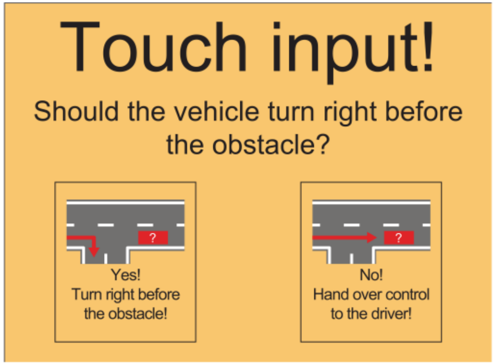
Cooperative Assistant Demo



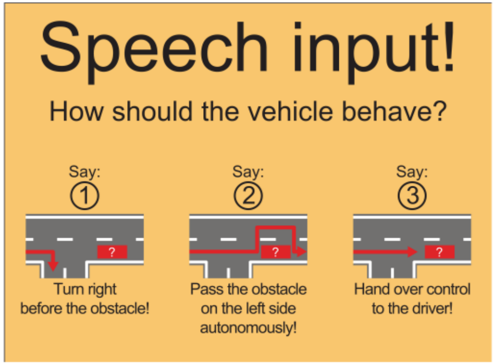
(a) Alert and explanation (b) Interaction request (c) Proposition accepted (d) Take-over request

Figure 2: Cooperative assistant: it first alerts and informs the driver (2a) before asking the driver what to do (2b). The assistant gives feedback when the driver selects an autonomous driving proposition (2c) or a take-over request otherwise (2d).

Input Methods



(a) Interaction request with 2 options. The participant has to select the desired option via touch.

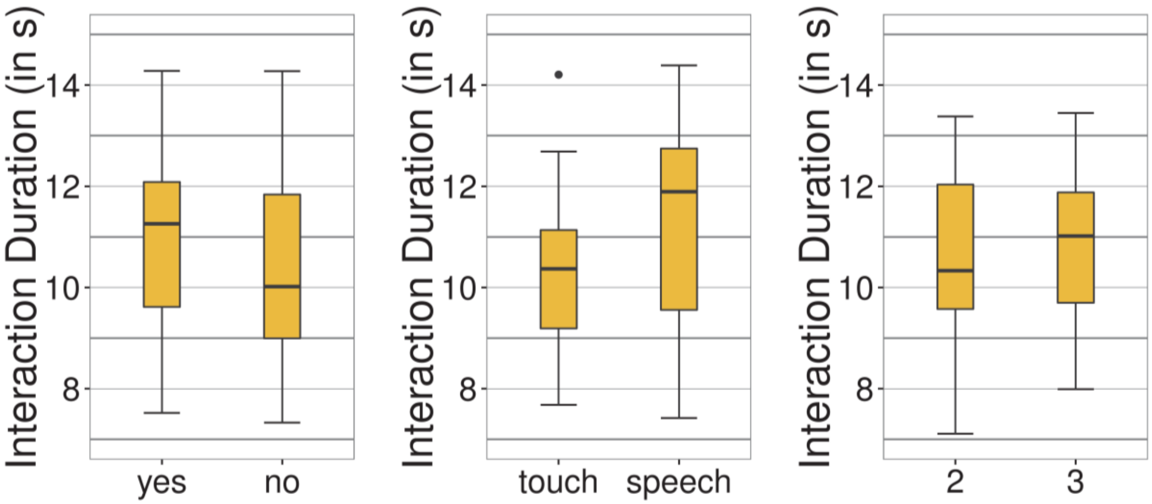


(b) Interaction request with 3 options. Participants select the desired option via saying the according number.

Figure 5: Screenshots of the interaction requests on the tablet in the center console. The input modality was displayed on the top of the screen.

Performance

Interaction Duration



(a) Executability (b) Interaction modality (c) Options

Participant Opinion

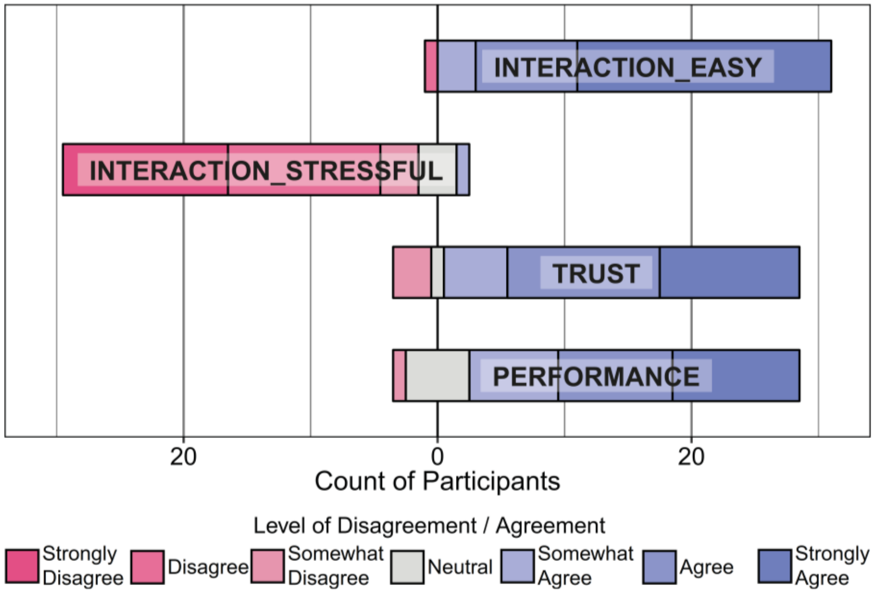


Figure 7: (Dis-) agreement of the participants on 7-point Likert scales to statements regarding the ease of interaction, the trust in automation and the perceived performance

Discussion

Simplicity	Small option count, implicit interaction
Supporting Driver Assessment	e.g. Highlighting road signs when asking for support
Mistrusting Speech Recognition	Robust; touch as fallback

Discussion – cont'd

Rear-view mirror	Limitation in responsible decision
Reward System	Participant engagement
Participant Group	Mean and SD, age range

Discussion – cont’d

Trust Interactions	Only clear communication and multiple modes of interaction was in focus
Time Restrictions	How much time will remain for the driver to communicate with the car?
Opportunities to Explore	Personalization; Cooperation vs Handover; Complacency

Next Iterations

1

Figure 4: Fixed-base driving simulator of the Department Human Factors at Ulm University.

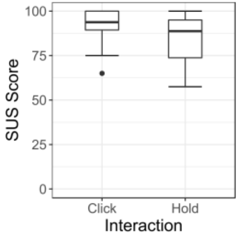


Figure 6: SUS scores.

2

Figure 1: Experimental setup: Participants saw the game [21] either on the flat screens in front of them (traffic scene and a speedometer) or via a VR HMD (see in-cockpit scene in Figure 2).

Figure 2: In-cockpit perspective (VR condition) of the racing game [21]: In contrast to the flat screen condition the headset displayed the cockpit including a virtual body of the driver.

Walch, Marcel, et al. "Click or Hold: Usability Evaluation of Maneuver Approval Techniques in Highly Automated Driving." Extended Abstracts of the 2018 CHI Conference on Human Factors in Computing Systems. ACM, 2018.
Walch, Marcel, et al. "Evaluating VR driving simulation from a player experience perspective." Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems. ACM, 2017.

Thank you for your attention