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The Influence of Feelings while Driving Regular Cars on the Perception and Acceptance of Self-Driving Cars

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Abstract

Self-driving vehicles will affect the future of transportation, but factors that underlie perception and acceptance of self-driving cars are yet unclear. Research on feelings-as-information and the affect heuristic has suggested that feelings are an important source of information, especially in situations of complexity and uncertainty. In this study ($N = 1,484$), we investigated how feelings related to traditional driving affect risk perception, benefit perception and trust related to self-driving cars as well as people's acceptance of the technology. Due to limited experiences with and knowledge of self-driving cars, we expected that feelings related to a similar experience, namely driving regular cars, would influence judgments of self-driving cars. Our results support this assumption. While positive feelings of enjoyment predicted higher benefit perception and trust, negative affect predicted higher risk and higher benefit perception of self-driving cars. Feelings of control were inversely related to risk and benefit perception, which is in line with research on the affect heuristic. Furthermore, negative affect was an important source of information for judgments of use and acceptance. Interest in using a self-driving car was also predicted by lower risk perception, higher benefit perception and higher levels of trust in the technology. Although people's individual experiences with advanced vehicle technologies and knowledge were associated with perceptions and acceptance, many simply have never been exposed to the technology and know little about it. In the absence of this experience or knowledge, all that is left is the knowledge, experience and feelings they have related to regular driving.

KEY WORDS: Self-driving cars; affect heuristic; feelings as information

1. INTRODUCTION

Driving is the primary mode of transportation for the vast majority of adults in the United States, with 222 million licensed drivers (Federal Highway Administration, 2015) and 85.6% commuting by car (Bureau of Transportation Statistics, 2017). There are many reasons for these high numbers,

ranging from the limited quality and coverage of public transit systems to individuals' needs for schedule flexibility (Donorfio, D'Ambrosio, Coughlin, & Mohyde, 2009; Vanderbilt, 2008). Driving is also popular because many people report pure enjoyment around the experience of driving; they may feel happy about the sense of freedom or independence they may have while driving. Despite the joy driving may engender for many, it is not always a pleasurable experience. People also feel rage or anger at traffic conditions or the behaviors of other drivers, and driving in certain environments and contexts can lead to stress, such as when one is driving on unfamiliar roads, in poor weather, in heavy traffic, or running late (Vanderbilt, 2008). The negative emotions that driving may engender in some people have also been found to be connected to a greater likelihood of crashes (Abdu, Shinar, & Meiran, 2012; Berdoulat, Vavassori, & Sastre, 2013; Dingus et al., 2016).

Self-driving cars have not yet entered consumer markets, but they have the potential to make driving safer and travel more efficient. The World Health Organization reported in 2016 that road traffic injuries were the leading cause of death among people aged 15 to 29 (World Health Organization, 2016). In the US alone, over 37,000 people died in car crashes in 2016 (National Highway Safety Traffic Administration., 2017). Removing human error from driving is one of the greatest potential benefits of self-driving cars, as driver error could be directly or indirectly responsible for as many as 94% of all traffic accidents (National Highway Safety Administration, 2015). Beyond decreasing the risk of an accident, self-driving cars have the potential to decrease congestion, increase mobility, and yield more efficient use of commuting time. The rapidly growing population of older drivers may especially benefit from self-driving cars (Center for Disease Control, 2016). Physical and cognitive declines associated with age often lead to a decrease in driving abilities and limitations in mobility (Anstey & Wood, 2011), which in turn may leave people at a greater risk for depression, social isolation, and other negative health outcomes (Chihuri et al., 2016; Marottoli et al., 1997). Self-driving cars have the potential to reduce or eliminate the negative outcomes associated with restricted mobility in an aging population.

It remains unclear, however, when or if self-driving vehicles will move from novelty in the news to normal fixtures on the nation's highways. Aside from the technical requirements inherent in such a complex system, there is a question of people's reactions to the technology. Previous work has found that people's risk and benefit perceptions as well as trust in the technology are related to its acceptance (Bearth & Siegrist, 2016; Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978; Frewer, Howard, & Shepherd, 1995; Siegrist, 2000), particularly for new innovations (Lee & See, 2004; Lee, 2009; Luo, Li, Zhang, & Shim, 2010). Here we examine the proposition that people's assessments of self-driving vehicles will be shaped by affect; it is always present when people make judgments (Zajonc, 1980), and previous research has demonstrated that risk and benefit perceptions of new technologies are often driven by feelings (Slovic & Peters, 2006; Slovic, Finucane, Peters, & MacGregor, 2004). In this research, we specifically examine how people's feelings around driving traditional cars may affect their perceptions of risk and benefit of and trust in self-driving cars. Further, we investigate how these feelings, perceptions and trust in turn influence people's acceptance of the technology.

1.1. Public Perception of Risk

Laypeople often evaluate the risks and benefits of new technologies differently than experts, and their perceptions of risk are also shaped by their perceptions of benefits the technology may offer. For laypeople, risk perception tends to decrease when benefit perception increases, and vice versa (Alhakami & Slovic, 1994). Past work has shown that laypeople's perceptions of a new technology can be affected by the characteristics of the technology itself and individual-level variables (see Visschers & Siegrist, 2018 for an overview).

The characteristics of the technology itself can be captured by two orthogonal dimensions: dread risk and unknown risk. The more dreadful and unknown a new technology is thought to be, the greater the public's risk perception of it (Slovic, 1987; 2015). Dread risks include people's perceptions of the potential for lack of control, catastrophic outcomes and fatalities. Unknown risks include perceived newness, lack of scientific knowledge, unobservable consequences and delay of effects. These two dimensions of risk explain why some hazards are perceived as riskier than others by the public, despite contrary statistical information from experts. As a result, familiarity may breed contempt: common actions and activities are often not perceived as especially risky compared with the unfamiliar or the novel (Hengstler, Enkel, & Duelli, 2016). For example, objectively risky activities such as alcohol consumption or driving, which are perceived as non-dreadful and familiar, are also perceived as not very risky by the public (Fox-Glassman & Weber, 2016).

Individual-level factors that affect people's perceptions of risk include knowledge and affective associations. People's levels of knowledge about a technology should affect the extent to which they understand both its risks and benefits. Levels of subjective knowledge, or self-assessed knowledge, have been associated with lower risks and greater benefits assessments and a greater likelihood of acceptance of the technology. In contrast, objective measures of knowledge have mixed impacts on risk and benefit assessments (Cousin & Siegrist, 2010; Visschers & Siegrist, 2018). Further, people's affective evaluations shape their risk assessments of new technologies, as affect can serve as a "mental shortcut [relative to developing the expertise to assess the risks and benefits of a technology scientifically] in which people rely on the positive or negative valence associated with a hazard to judge its benefits and risks" (Visschers & Siegrist, 2018, p.11). Affect is often more significant in judgments under uncertainty or in complex situations where people might lack the knowledge, experience and/or the capacity to make a judgment, because their affective responses serve as cues to simplify decisions (e.g., Lerner, Li, Valdesolo, & Kassam, 2015; Loewenstein & Lerner, 2003; Slovic et al., 2004).

1.2. Feelings as Information

As noted above, affect, in the form of a subtle feeling of positivity or negativity, can serve as a decision heuristic that people use in situations of uncertainty and limited knowledge, known as the *affect heuristic* (Slovic & Peters, 2006; Slovic, Finucane, Peters, & MacGregor, 2003). People's use of feelings as a general source of information was extensively discussed by Schwarz and Clore (Schwarz, 2012; Schwarz & Clore, 1983; 2003), who termed it the "How do I feel about it heuristic." The source of feelings that people use to make judgments is not necessarily directly related to the stimulus at

hand. *Integral* affect is directly related to a stimulus, but *incidental* affect is independent of the stimulus, and may result in misattribution and biased judgments (Lerner et al., 2015; Loewenstein & Lerner, 2003).

Both integral and incidental affect serve several functions in the formation of judgments: information; common currency; spotlight; and motivator (Peters, Västfjäll, Gärling, & Slovic, 2006). When affect serves as information to judge a new technology, for example, decision makers simply consider how they feel about it (Schwarz, 1990; Schwarz & Clore, 2003). The basis of these feelings is often prior experiences or thoughts related to the decision at hand (integral affect), but it could also be a less relevant emotional state such as current mood (incidental affect; Peters et al., 2006). When affect serves as common currency, different pieces of complex information can be compared in terms of the affective responses they evoke in order to simplify the judgment process (Cabanac, 1992). Affect as a common currency extends the affect-as-information approach and allows simple comparisons of positive and negative feelings rather than having to weight arguments (Tompkins, Bjälkebring, & Peters, 2018). Affect as spotlight leads people to focus on new information in the form of feelings (e.g., strong vs. weak, specific emotions), which in turn are used to guide judgment (Peters et al., 2006). Affect can also motivate information processing and lead to approach or avoidance behaviors (Chen & Bargh, 2016). Because people aim to maintain positive mood states, even incidental mood can motivate behavior (Isen, 2000). For example, Hirshleifer and Shumway (2003) reported that weather influenced stock market returns in 26 countries from 1982 to 1997; sunshine in the city that hosted the country's major stock exchange increased the likelihood that the market went up. Presumably sunshine improved investors' moods, which rendered them more optimistic about the future of the economy.

The nature or valence of the affect plays a role in how it is weighed in judgments. In particular, people tend to attend to or weight negative information or emotions more heavily than positive ones when making evaluations. People can report more negative emotion words than positive ones; they are more likely to recall events that are negatively emotionally charged compared with positive ones; and negative affect may prompt more cognitive processing than positive affect (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Forgas, 1995; Schwarz & Clore, 2003). Thus, while both positive and negative affect may have significant and independent effects on people's evaluations, negative affect may be more heavily weighted or important to people's judgments.

The affect heuristic also serves as one explanation for the inverse relationship between risk and benefit assessments. If people's emotional responses are more positive, they tend to judge risks to be lower and benefits to be higher; the more negative people's affective reactions are, the more likely they are to judge risks to be higher and benefits to be lower (Alhakami & Slovic, 1994; Slovic et al., 2004). People may be particularly more likely to rely on their affective reactions as a common source to generate both their risk and benefit evaluations when they lack expertise within a given domain (Finucane, Alhakami, Slovic, & Johnson, 2000; Sokolowska & Slebocka, 2015).

In sum, affect is often used to inform more complex decision problems. This impact of affect tends to be more prominent under conditions characterized by higher levels of uncertainty (Faraji-

Rad & Pham, 2017), less familiarity (e.g., Srull, 1984), and in more complex situations. Finally, negative affect may be more significant in shaping people's judgments than positive affect (Baumeister et al., 2001).

1.3. Technology Acceptance

The affect heuristic suggests that affect shapes people's willingness to adopt new technologies to the extent that the technology is novel, its performance is uncertain, and its impacts are unknown. In a recent review of the technology adoption literature, combined with user interviews, a number of different factors that contribute to people's willingness to accept and use new technologies were identified, of which emotion is one: "Part of the attraction to any new product is its ability to link the user to something they feel" (Lee & Coughlin, 2015, p. 753). Two additional variables Lee and Coughlin (2015) consider in their review, usability and value, map on to ease of use and perceived usefulness, key constructs from the widely used Technology Acceptance Model (TAM; Davis, Bagozzi, & Warshaw, 1989). Perceived usefulness or the perceived potential benefits has been shown in some empirical work to be a more significant factor in explaining adoption than ease of use (Lee, Ward, Raue, D'Ambrosio, & Coughlin, 2017).

Other factors that have been identified as significant for understanding technology adoption include the relevance of people's previous experiences (including with the technology) and system reliability – the ability of the system "to work without failure" (Lee et al., 2017). The concept of system reliability, or the belief that the system will work as described, is a form of trust in the technology; it is in essence the belief that the technology will deliver on its promised performance. Other research has also suggested that trust in the technology may be a predictor of acceptance (Abraham et al., 2016; Balfe, Sharples, & Wilson, 2018; Choi & Ji, 2015; Lee & See, 2004; Zmud, Sener, & Wagner, 2016).

While other factors such as accessibility or market availability are more important for explaining technology acceptance for currently available technologies, emotion or affect should be particularly important in influencing new technology adoption when people have limited knowledge of and exposure to the technology and are uncertain about whether it will work, and when the wider effects of the technology are unclear. Further, individual characteristics such as age, gender, lifestyle, and comfort levels with different technologies may also affect people's willingness to adopt new technologies (Lee et al., 2017; Venkatesh, Thong, & Xu, 2012).

1.4. Current Research on Acceptance of Self-Driving Cars

Although fully self-driving cars have yet to enter the consumer market, there is a growing body of research that attempts to understand the public's attitudes toward and likely acceptance of these vehicles. Studies have found that people's degree of acceptance varies by individual characteristics, with younger, male or more tech savvy people generally more interested in using self-driving cars than older, female or less tech savvy people (Hohenberger, Spörrle, & Welp, 2016; König & Neumayr, 2017; Lee et al., 2017; Nielsen & Haustein, 2018).

Several studies have found that while most people do not embrace the technology completely, neither are they completely opposed to it. In particular, people anticipate that the technology could deliver benefits such as: fewer crashes, reduced severity of crashes, lower vehicle emissions, better fuel economy, transportation solutions for older and disabled people, the possibility to engage in other activities while on the road, greater safety, and greater convenience (Howard & Dai, 2013; Hulse, Xie, & Galea, 2018; Nielsen & Haustein, 2018; Sanbonmatsu, Strayer, Yu, Biondi, & Cooper, 2018; Schoettle & Sivak, 2014).

Although the technology offers many promises, people typically harbor a number of reservations about it (König & Neumayr, 2017). Concerns people have include the overall safety and reliability of the technology, including the chances that the vehicles could be confused by unexpected situations; people fear the possibility of equipment failure (Bansal & Kockelman, 2016; Bansal, Kockelman, & Singh, 2016; Shabanpour, Golshani, Shamshiripour, & Mohammadian, 2018). Other risks people perceive around the technology are unresolved legal liability issues, hacking, and the potential disclosure of personal data or of tracking (Howard & Dai, 2013; König & Neumayr, 2017; Kyriakidis, Happee, & de Winter, 2015; Schoettle & Sivak, 2014; Shabanpour et al., 2018).

People's hesitations around the acceptance of automated vehicle technologies may also be tied to their feelings around driving itself, and many people report driving to be positive for them. For example, in a study that compared all levels of automation (from manual [fully human controlled] to fully automated), participants found manual driving the most enjoyable (Kyriakidis et al., 2015). In another study, most people were willing to accept automated features that assisted the driver while the driver remained in control, but fewer people were comfortable with full automation (Abraham et al., 2018). Consistent with these results, yielding control was a major barrier to adoption of self-driving cars among regular commuters (Howard & Dai, 2013). Because self-driving cars represent a fundamental change in the driving task, people's current feelings about driving traditional vehicles may shape how they assess changes or alternatives to it.

1.5. The Present Study

The present study focuses on how feelings experienced while driving influence risk and benefit perceptions as well as trust in self-driving cars and how, in turn, these perceptions affect the acceptance of these vehicles. Based on the affect heuristic and the feelings-as-information approach, we assume that people will use their feelings about driving their current vehicles to judge self-driving cars because of their limited knowledge or experience with automated vehicle technology itself. We hypothesize that feelings related to their experience as drivers of regular cars may carry-over when judging self-driving cars (e.g., Lerner et al., 2015; Peters et al., 2006). Further, because self-driving cars represent a change to the driving status quo, how people feel about driving now should affect how they react to a potential change to it. In particular, we assume that people's affective experiences with their own driving rather than a deliberate analysis of advantages and disadvantages will in part shape their judgments of self-driving cars. Because the affect measures are related to a different technology than the outcome, however, we approached this question in an exploratory manner and formulated the following research question: How do feelings related to

human-operated driving influence risk and benefit perceptions of, as well as trust in, self-driving cars?

Based on other literature that has examined people's risk and benefit perceptions and trust, we entered additional predictors related to gender, knowledge (about self-driving cars, but also whether participants knew of any accidents involving self-driving cars) and experience. We asked about driving experience, but also experience with vehicle automation features currently on the market (e.g., cruise control, lane keeping, collision avoidance systems). Education was included as an additional control variable (for an overview see Chauvin, 2018; Visschers & Siegrist, 2018).

Further, we assumed that acceptance of self-driving cars would be predicted by people's risk and benefit perceptions of and trust in the technology. Based on previous research, we expected that high benefit perceptions and high trust would increase acceptance of self-driving cars, while high risk perceptions would decrease acceptance (Davis et al., 1989; Lee & See, 2004; Siegrist, 1999). Drawing on models of technology acceptance (Lee & Coughlin, 2015; Venkatesh et al., 2012), people's affective reactions to driving, knowledge, experience and gender were included in the model. Education was again added as a control variable.

2. METHOD

2.1. Participants

We conducted a nationwide online survey in the United States in summer 2016 of 1,748 participants who were recruited through Qualtrics, an online market research company. The majority of participants had a valid driver's license at the time of data collection (89.2%); those who did not were excluded from the analysis. We also excluded participants who gave nonsensical answers (e.g., birthyear before 1900, random letters when asked to describe what a self-driving car was in their own words). The remaining 1,484 participants were between the ages of 18 and 89 ($M = 49.87$, $SD = 17.73$, 45% female). Of those participants, 80% were white, 8% black, 5% Asian American, 3% Latinx, and 4% identified as other or multiracial. Most participants had a college degree (27%) or some college (25%), 17% had a post-graduate degree or had completed some post-graduate work, 12% had an associate's degree, and 19% had a high school diploma. About one-third of participants were employed full-time (34%), 10% were employed part-time, 9% were not employed, 6% were self-employed, 29% were retired, 4% were students, and 8% homemakers. The majority of participants had annual household incomes below \$74,999 (51% less than \$50,000 and 21% below \$25,000), 15% had incomes between \$75,000 and \$99,999, and 12% had incomes of \$100,000 or more.

2.2. Measures

Knowledge of self-driving cars was measured by two variables: participants' self-reported knowledge and an indicator for whether they had heard any media stories about accidents involving self-driving cars (see Table 1 for details on the items included in this analysis). Following the self-reported knowledge measure in the beginning of the questionnaire, respondents were then provided the following definition of a self-driving car: "For the purpose of this study, we define self-driving cars as

those in which operation of the vehicle occurs without the driver controlling the steering, acceleration, and braking; the driver is not expected to constantly monitor the roadway.” Risk and benefit perceptions were captured by respondents indicating how risky and how beneficial they thought it was to use a self-driving car. We measured participants’ trust in a self-driving car to work reliably under certain conditions with three items that were scaled together. Willingness to adopt or accept self-driving cars was measured by self-reported interest in using them and, at a later point in the questionnaire, by asking people whether they would let a child (under 5 years, between 5 and 12 years, and between 13 and 17 years of age) use a self-driving car alone. The latter use cases for self-driving cars correspond roughly to different developmental stages for children – preschool, childhood and adolescence, respectively.

Participants indicated for how long they had been drivers and how many days a week they drove. Most of the participants self-reported as frequent drivers, with 67.4% driving at least five days per week and 34.2% driving every day. Years as a driver and age were strongly and positively correlated, $r = .95, p < .001$, so in the following analyses we included only years as a driver in the model. We further asked participants about their experience with advanced vehicle technologies currently on the market.

Participants used the Positive and Negative Affect Schedule (PANAS) to report feelings they typically experienced while driving (PANAS; Watson, Clark, & Tellegen, 1988). The PANAS has been used before in other studies on public acceptance of new technologies (Lara, Pascual, Borondo, & Pino, 2016; Pelegrín-Borondo, Reinares-Lara, & Olarte-Pascual, 2017; Turner, Love, & Howell, 2008) and has been well validated as a measure of affect. The questionnaire concluded with additional demographic items.

Table 1. Items used in the study

Variable	Item Wording	Response Options	<i>M (SD) or % yes</i>
Knowledge			
Knowledge about self-driving cars	How much do you know about self-driving cars?	From 1 (no knowledge) to 5 (a great deal of knowledge)	2.59 (1.03)
Heard of self-driving car accident	Have you heard any stories about self-driving cars that have been involved in accidents or fatalities?	Yes, No, Do not know	35.1%
Experience			
Experience with advanced vehicle technologies	Please indicate how much experience you have with each vehicle technology	From 1 (very little experience) to 5 (a great deal of experience)	2.02 (1.03)
	- Cruise control		
	- Adaptive cruise control		
	- Adaptive/smart headlights		

- Automatic emergency braking
- Autopilot
- Blind spot detection
- Forward collision warning
- Lane centering/lane keeping assist
- Lane departure warning
- Parking assist
- Pilot assist
- Traffic jam assist

$\alpha = .95$

Years as a driver For how many years have you been a driver? Open answer (years) 31.19 (18.55)

Driving frequency On average, how many days a week do you drive? Open answer from 0 to 7 5.15 (1.81)

Feelings

PANAS For each of the following, please select how much you feel like this when you are driving (items were randomized): From 1 (very slightly or not at all) to 5 (extremely) PA-Enjoyment: 3.06 (1.00)
PA-Control (attentive, alert): 4.27 (0.79)
NA: 1.42 (0.64)

Positive Affect (PA): Excited, Determined, Strong, Proud, Inspired, Active, Alert, Interested, Attentive, Enthusiastic

$\alpha = .89$ (PA-Enjoyment $\alpha = .91$, PA-Control $\alpha = .68$)

Negative Affect (NA): Afraid, Irritable, Guilty, Hostile, Ashamed, Nervous, Distressed, Jittery, Scared, Upset

$\alpha = .93$

Perceptions & Trust

Risk perception How risky do you think it is to use a self-driving car? From 1 (not at all) to 5 (very much) 3.24 (1.12)

Benefit perception How beneficial do you think it is to use a self-driving car? From 1 (not at all) to 5 (very much) 3.07 (1.24)

Trust in self-driving cars How much would you trust self-driving cars to do the following? From 1 (low trust) to 5 (high trust) 2.69 (1.13)

- Work reliably
- Work properly in poor weather conditions
- Work properly on old streets in need of repair

$$\alpha = .92$$

Acceptance

Interest in using a self-driving car	How interested are you in using a self-driving car?	From 1 (not at all) to 5 (very much)	2.58 (1.41)
Willingness to let a child use a self-driving car	Would you let a child use a self-driving car alone?	Yes, No, Do not know	
	- A child who is under 5 years old		- 1%
	- A child who is between 5 and 12 years old		- 3.2%
	- A child who is between 13 and 17 years old		- 18.9%

2.3. Feelings Related to Driving

The driving experience can engender a number of different emotions spanning various intensities and dimensions of positivity and negativity. We conducted an exploratory factor analysis of the 20 PANAS items with principal factor extraction and varimax rotation. The Keiser-Meyer-Olkin (KMO) indicated an adequate sample (KMO = .94), and Bartlett's Test of Sphericity indicated strong collinearity, $\chi^2(190) = 17229.47, p < .001$. The extraction revealed three factors with Eigenvalues greater than 1, with 63.75% of the cumulative variance explained (32.81%, 24.51%, and 6.43% for each factor). The negative affect (NA) scale was identified as the first component, but the items that traditionally make up the positive affect (PA) scale were split into two factors which we labeled *control* (attentive, alert) and *enjoyment* (remaining positive items). Table II displays a correlation matrix of the key variables included in the analysis.

3. RESULTS

Table II. Correlations of all variables

	1	2	3	4	5	6	7	8	9	10
1 Self-reported knowledge of self-driving cars										
2 Experience with advanced vehicle technologies	.42**									
3 Years as a driver	-.31**	-.35**								
4 Driving frequency	.15**	.21**	-.15**							

5	Positive affect - enjoyment	.26**	.46**	-.14**	.17**						
6	Positive affect - control	.01	-.03	.17**	-.03	.31**					
7	Negative affect	.22**	.29**	-.38**	.03	.14**	-.20**				
8	Risk perception	-.09**	-.10**	.07**	-.01	-.01	.07**	.02			
9	Benefit perception	.37**	.35**	-.30**	.09**	.25**	-.06*	.22**	-.46**		
10	Trust in self-driving cars	.38**	.43**	-.28**	.13**	.27**	-.05	.21**	-.49**	.64**	
11	Interest in using a self-driving car	.45**	.43**	-.39**	.11**	.28**	-.08**	.28**	-.44**	.80**	.69**

* $p < .05$, ** $p < .01$.

$N = 1484$

3.1. Perceptions of Self-Driving Cars

To examine the influence of feelings related to driving on risk perception, benefit perception and trust in self-driving cars, we conducted linear regression analyses. The results of these analyses are shown in Table III. Higher risk perception was predicted by less experience with advanced vehicle technologies, higher levels of positive affect (control), higher levels of negative affect experienced while driving, and being female. Higher benefit perception was related to having fewer years as a driver, greater self-reported knowledge of self-driving cars, more experience with advanced vehicle technologies, lower levels of positive affect (control), higher levels of positive affect (enjoyment), higher levels of negative affect, and being male. Trust in self-driving cars was related to having fewer years as a driver, greater self-reported knowledge of self-driving cars, more experience with advanced vehicle technologies, no knowledge of any accidents involving a self-driving car, positive affect (enjoyment) experienced while driving, and being male.

Table III. Regression Analyses: Risk Perception, Benefit Perception, and Trust as Dependent Variables

Dependent Variable	<i>Risk Perception</i>			<i>Benefit Perception</i>			<i>Trust in Self-Driving Cars</i>			
	<i>b</i>	S.E.	β	<i>b</i>	S.E.	β	<i>b</i>	S.E.	β	
Technology Knowledge										

Self-reported knowledge of self-driving cars	-0.06	0.03	-0.05	0.26*	**	0.03	0.22	0.23*	**	0.03	0.21	
Heard of self-driving car accident ²	0.11	0.06	0.05	-0.09	0.06	-0.04	-0.14*	0.06	-0.06			
Experience												
Experience with advanced vehicle technologies	-0.09*	0.04	-0.08	0.16*	**	0.04	0.13	0.26*	**	0.03	0.24	
Years as a driver	0.003	0.002	0.05	-	0.009	***	0.002	-	0.006	***	0.002	-0.10
Frequency of driving per week	0.02	0.02	0.03	-0.01	0.02	-0.02	0.003	0.02	0.004			
Affect												
Positive affect: control	0.10*	0.04	0.07	-0.09*	0.04	-0.06	-0.06	0.04	-0.04			
Positive affect: enjoyment	0.01	0.04	0.01	0.15*	**	0.04	0.12	0.10*	*	0.03	0.09	
Negative affect	0.15*	*	0.05	0.08	0.11*	0.05	0.06	0.05	0.05	0.03	0.03	
Demographics												
Gender ¹	0.16*	*	0.06	0.07	-0.15*	0.06	-0.06	-0.13*	0.05	-0.06		
Education	-0.02	0.02	-0.02	0.01	0.02	0.02	0.02	0.02	0.02	0.03		
R^2		.03			.22			.258				
$F(df_1, df_2)$		4.55***	(10, 1473)		42.35***	(10, 1473)		51.27***	(10, 1473)			

¹Gender was coded 0 = men, 1 = women

²Variable was coded as 0 = no / do not know, 1 = yes, heard stories

* $p < .05$, ** $p < .01$, and *** $p < .001$.

3.2. Acceptance of Self-Driving Cars

3.2.1. Interest in Using a Self-Driving Car

To investigate the influences of risk perception, benefit perception and trust on acceptance of self-driving cars, we conducted linear regression analyses with the dependent variable *interest in using a self-driving car*. We included the same variables as in the previous analyses to measure their direct influence on interest in using a self-driving car, but added risk perception, benefit perception and trust in self-driving cars to the model. The results of this analysis are displayed in Table IV. Risk perception, benefit perception and trust were all significant predictors, but benefit perception had the largest effect size among the three. Experiencing more negative affect when driving regular cars, more experience with advanced vehicle technologies, greater self-reported knowledge of self-driving cars, and fewer years as a driver were also related to interest in using a self-driving car. The effect size of risk perception was smaller compared with those for benefit perception and trust, which is consistent with the smaller explained variance in the model for risk perception (3%) as opposed to the models for benefit perception (22%) and trust (26%). Overall, this model accounted for over 72% of variance in the interest in use variable.

Table IV. Regression Analyses: Interest in Using a Self-Driving Car as Dependent Variable

Dependent Variable	<i>Interest in Using a Self-Driving Car</i>		
	<i>b</i>	S.E.	β
Risk perception	-0.09***	0.02	-0.07
Benefit perception	0.60***	0.02	0.53
Trust in self-driving cars	0.27***	0.03	0.22
Knowledge			
Self-reported knowledge of self-driving cars	0.15***	0.02	0.11
Heard of self-driving car accident ²	-0.08	0.04	-0.03
Experience			
Experience with advanced vehicle technologies	0.05*	0.02	0.04
Years as a driver	-0.007***	0.001	-0.10
Frequency of driving per week	-0.007	0.01	-0.01

Affect

Positive affect: control	-0.03	0.03	-0.02
Positive affect: enjoyment	0.03	0.02	0.02
Negative affect	0.08*	0.03	0.03

Demographics

Gender ¹	-0.009	0.04	-0.003
Education	0.004	0.01	0.005
R^2		.72	
$F(df_1, df_2)$		294.33***	(13,1470)

¹Gender was coded 0 = men, 1 = women;

²Variable was coded as 0 = no / do not know, 1 = yes, heard stories

* $p < .05$, ** $p < .01$, and *** $p < .001$.

3.2.2. Acceptance of self-driving cars in special use conditions

An alternative measure of acceptance was whether participants would let a child ride in a self-driving car alone. In general, respondents were reluctant to do so. Only 1% of participants indicated that they would let a child under age 5 use a self-driving car alone. Slightly more (3.2%) would let a child between ages 5 and 12 use a self-driving car alone and 18.9% ($n = 280$) a child between 13 and 17 years of age. To explore the impact of risk and benefit perceptions, trust, knowledge, experience, and affect on this measure of acceptance, we conducted a logistic regression with whether one would let a child between the ages 13 and 17 ride in a self-driving car alone as the dependent variable (see Table V; analyses for the younger age groups were not conducted due to the small number of those who would let a child ride alone). In line with the results in Table IV on interest in using a self-driving car (interest in use), this analysis revealed that risk perception, benefit perception and trust were all significant predictors of likelihood of agreeing to let a child ages 13 to 17 use a self-driving car alone: greater risk perception was associated with a reduced likelihood, and greater benefit perception and greater trust were associated with a greater likelihood. Unlike the interest in use results, neither of the knowledge variables was a significant predictor, and only years of experience as a driver was significant among the experience variables; participants with fewer years of driving experience were more likely to say that they would let a child ages 13 to 17 ride in a self-driving car alone. Consistent with the interest in use results, experiencing more negative affect

when driving regular cars was associated with a greater likelihood of agreeing to let a child use a self-driving car alone, and neither of the positive affect measures was significant. Different from the interest in use model, however, was that negative affect, benefit perception and trust all had similar impacts (in terms of effect size) on the dependent variable. Also different from the interest in use model was that gender and higher levels of education were significant predictors of people's likelihood of agreeing to let a child ages 13 to 17 use a self-driving car alone. People with higher levels of education and men were more likely to agree to let them to ride alone.

Table V. Logistic Regression: Would you let a child between the ages of 13 and 17 ride in self-driving car alone?

Dependent Variable	<i>Let a child ride alone</i>		
	<i>b</i>	S.E.	Exp(B)
Risk perception	-0.32***	0.08	0.72
Benefit perception	0.46***	0.09	1.58
Trust in self-driving cars	0.39***	0.10	1.48
Knowledge			
Knowledge about self-driving cars	0.06	0.09	1.06
Heard of self-driving car accident ²	-0.08	0.17	0.93
Experience			
Experience with advanced vehicle technologies	-0.03	0.09	0.97
Years as a driver	-0.02**	0.005	0.98
Frequency of driving per week	-0.08	0.05	0.93
Affect			
Positive affect: control	-0.008	0.10	0.99
Positive affect: enjoyment	-0.009	0.10	0.99
Negative affect	0.30**	0.11	1.35
Demographics			
Gender ¹	-0.66***	0.16	0.52

Education	0.10*	0.05	1.10
R^2 (Nagelkerke)		.31	
χ^2 (df) Model		310.30***(13)	

¹Gender was coded 0 = men, 1 = women;

²Variable was coded as 0 = no / do not know, 1 = yes, heard stories

* $p < .05$, ** $p < .01$, and *** $p < .001$.

4. DISCUSSION

Judging whether one would use a self-driving car without ever having seen one or experienced riding in one is a difficult task. When judgments involve complexity and uncertainty, people often rely on how they *feel* about it rather than engaging in effortful reasoning about arguments for their judgments. Drawing on decades of research on feelings as a source of information and decision heuristic (e.g., Lerner et al., 2015; Loewenstein & Lerner, 2003; Schwarz, 1990; Slovic & Peters, 2006; Zajonc, 1980), we hypothesized that people use their feelings to inform their judgments of self-driving cars. In this case we examined how feelings about a similar well-known technology, namely traditional driving, shaped people's perceptions about a slightly different technology, self-driving cars. The results of this work not only contribute to an understanding of people's perceptions and acceptance of self-driving cars, but also have theoretical implications in demonstrating that feelings about a target or an experience similar to that being judged can serve as information that shapes assessments. Further, the analysis here reinforces the importance of considering the multidimensional nature of affect (see Lerner et al., 2015 for a discussion). Instead of simply positive and negative PANAS factors, our data revealed three factors, with items traditionally capturing positive affect splitting into two variables that we labeled enjoyment and control.

4.1. Risk and Benefit Perception and Trust

Our results indicate that feelings experienced while driving regular cars inform people's risk and benefit perceptions of as well as their trust in self-driving cars (e.g., Schwarz, 1990; Zajonc, 1980). We asked about people's affective experiences driving traditional vehicles—not self-driving cars; nevertheless, people's feelings about the more familiar driving of current vehicles carried over to their assessments of self-driving cars. One possible explanation for the transfer of affective impact in this case is that self-driving cars essentially represent a change to the status quo, in which humans bear the obligation for the driving task. For people who do not enjoy the responsibilities of driving or

who find the driving experience to be burdensome or unpleasant (either because they would prefer to be doing something else or because they dislike the driving environment, for example), self-driving cars offer an enticing promise: people can still get where they need to go without having to navigate the driving experience and with the opportunity to use their driving time for some other tasks or purpose. As a result, one's attitudes about the status quo should inform perceptions of change to it.

In line with the literature (Baumeister et al., 2001), negative affect seems to be a particularly important source of information when judging both risks and benefits of self-driving cars. People who experienced high levels of negative affect had both higher risk and higher benefit perceptions of self-driving cars. This is contrary to what we would expect from research on the affect heuristic (Finucane et al., 2000), which suggests that negative affect should have opposite effects on risk and benefit perceptions. It may be possible, however, that participants who reported negative affect around driving may also have perceived certain specific or concrete features of self-driving cars to be beneficial – such as making the driving experience safer. This focus on certain details of the new technology would be in line with research showing that negative affect increases systematic processing of information (Forgas, 1995; Schwarz & Clore, 2003). While participants were not put in a negative mood, negative affect around driving may have still led to a more careful analysis of risks and benefits of self-driving cars. And when participants make judgments on a more concrete level, previous research has found that the inverse relationship of risk and benefit perceptions is reduced or eliminated (Sokolowska & Sleboda, 2015).

Unlike the risk and benefit models, trust was not influenced by negative affect. One possible explanation is that judgments of trust do not necessarily trigger an implicit comparison between the status quo and a new technology, which would lead people to rely on negative affect. A second possible explanation is that our measure of negative affect was about current driving and not self-driving cars. If our measure had been about self-driving vehicle technologies, we may have observed different results.

Positive affect (enjoyment), related to people's reports of excitement and enthusiasm around driving, predicted benefit perceptions of self-driving cars but not risk perception. Because positive affect is associated with more automatic processing, people who have more positive associations with driving may also be less inclined to deliberate about potential risks associated with self-driving cars. Thus, positive affect (enjoyment) may actually be capturing a positive attitude toward driving or mobility in general, regardless of vehicle type, yielding a relationship between positive affect and benefit perceptions of self-driving cars. For these people the value in driving may be more instrumental, rather than intrinsic.

This inverse relationship between risk and benefit perceptions is reflected in the impacts of positive affect (control) on these variables, although it was flipped: positive affect (control) was positively related to risk perception and negatively related to benefit perception. The change in status quo – from an active driver to a passive driver – may be perceived as a loss among those who value the feeling of control when driving. Loss aversion has a strong influence on human behavior (Kahneman,

Knetsch, & Thaler, 1991; Tversky & Kahneman, 1981); thus, an anticipated loss of control may result in negative affective reactions when judging self-driving cars. This negative affect would explain higher risk and lower benefit perception of self-driving cars.

Additional analysis with variables included in the survey indicates a strong positive correlation between positive affect (control) and confidence in one's ability to execute various driving tasks successfully (e.g., react quickly to a change in the environment, reverse a vehicle in a straight line), $r = .38, p < .01$ (see Table A1 for detailed results). Thus, those who reported more feelings of control while driving were also more likely to be people who reported greater self-confidence in their own driving skills or competency. As a result, they may be even more hesitant to give up driving in its current form as it is a skill they believe they perform well, and they may be more suspicious of a self-driving car's ability to handle the variety and complexity of driving challenges across a range of different environments as well as human operators do. Based on this, we should expect that the positive affect (control) variable should be negatively related to trust in self-driving cars: people who value their control and role as driver should be less likely to trust that a technology could replace what they do. The results in Table III are suggestive but not conclusive; the coefficient on the positive affect (control) variable is negative but is not statistically significant with a two-tailed test.

Taken together, our results suggest that affective information people have about driving influences their judgments about self-driving cars, but that when the affective measure is similar but not identical to the target, it is key to understand what the affect is capturing. Because control more directly links both types of technologies through the change in status quo (having control in one type of vehicle and having to give it up in the other), the affect heuristic may be applicable. Future studies should investigate how affect toward similar targets may influence judgments of the target, particularly in cases of new technologies. Work should also delve into these affective assessments to explore whether they represent more global evaluations (e.g., driving or mobility generally) or more specific contexts (e.g., driving human operated vehicles). The affect questions people answered were about "driving;" had they been asked about "driving your current vehicle" or "driving human-operated cars" the answers we received and the analysis of the positive affect (enjoyment) and negative affect variables may have differed.

Beyond the affect measures, as the risk perceptions literature would predict (Slovic, 1987; 2015), there was evidence that experience and knowledge shaped people's risk and benefit perceptions. People who had greater experience with advanced vehicle technologies had lower risk and higher benefit perceptions as well as higher trust ratings of self-driving cars, consistent with other literature on new vehicle technologies (Abraham et al., 2018; Balfe et al., 2018; Lee et al., 2018). Years of experience as a driver were not related to risk perception but were negatively related to benefit perceptions of and trust in self-driving cars. Thus, people with presumably greater levels of expertise as drivers were less likely to see the benefits of the technology – or of making a change to their mobility habits – and less likely to trust the technology to perform. Again, this may be a result of being averse to the potential loss of control and giving up a skill they manage well and have been engaged in for many years. Expertise as a driver, however, was unrelated to risk perception – newer and more experienced drivers alike were just as likely to see the risks self-driving cars posed.

Higher levels of self-reported knowledge were linked to higher perceived benefits of and higher levels of trust in self-driving cars, but like years of driving experience it was not associated with risk perceptions. People who thought they knew more and those who thought they knew less were just as likely to see the risks around self-driving cars. The other measure of knowledge, whether participants had heard any stories about accidents involving self-driving cars, was only associated with trust: those who said they had heard such stories reported lower trust levels in self-driving cars. Past work has shown that trust in particular can be quite fragile and can be easily destroyed by a single negative story (e.g., Slovic, 1999), so trust in self-driving cars may be more susceptible to the impact of negative information than risk and benefit assessments.

4.2. Acceptance of Self-Driving Car Technologies

In the second part of the analysis, we investigated how risk perception, benefit perception and trust in self-driving cars in turn affect interest in people's willingness to accept self-driving cars, as measured by interest in using a self-driving car and use by adolescents alone. In line with the literature (Davis et al., 1989; Lee & See, 2004; Siegrist, 1999), we found support for all three hypotheses that lower risk perception, higher benefit perception and higher levels of trust in self-driving cars were associated with greater interest in using a self-driving car. While the coefficients for all of these variables were statistically significant, the size of the coefficient for benefit perception on interest in using a self-driving car was particularly notable. This result is supported by the literature on technology adoption, which identified perceived benefits (or perceived usefulness of a technology) as well as trust in the technology (or system reliability), as significant factors underlying technology adoption (Davis et al., 1989; Lee & Coughlin, 2015).

We also assumed that affect should be particularly important in people's interest in using a self-driving car due limited knowledge of and exposure to this technology. When risk and benefit perceptions and trust in the technology were controlled, however, only higher levels of negative affect related to driving predicted greater interest in using a self-driving car; neither positive affect (control) nor positive affect (enjoyment) was a significant predictor. This result underscores the importance of negative affect as an antecedent of people's opinions (e.g., Baumeister et al., 2001; Zajonc, 1981) as well as the possibility that negative affect is more likely to carry over from a similar technology to predict the use of a new technology because it is related to more systematic processing.

In line with research on technology acceptance (e.g., Cousin & Siegrist, 2010; Lee & Coughlin, 2015), greater subjective knowledge of self-driving cars was positively related to interest in using them. Knowledge of any accidents involving self-driving cars did not predict interest in using them, once risk and benefit perceptions and trust in the technology were controlled for, but one question is how the findings here may have differed had the item been about ongoing or regular use of the technology, as opposed to a more generic "interest in use," which people might interpret as "trying the technology out some time." More experience with advanced vehicle technologies was positively related to interest in using self-driving cars, controlling for other variables in the model, but more experienced drivers were less interested in using self-driving cars. For these participants, driving may

have become a habit so ingrained in their daily lives that they saw little incentive to change from their current technology. This finding is of note because driving experience was so strongly correlated with age, and because older drivers might benefit particularly from self-driving cars if they confront health and functional challenges that impede their abilities to drive a human-operated vehicle safely (Anstey & Wood, 2011).

We measured technology acceptance with a second variable, people's willingness to let a child between the ages of 12 and 17 ride in a self-driving car alone. Similar to the interest in use measure, willingness to let a child ride alone was predicted by lower risk perception, higher benefit perception, higher trust in self-driving cars and higher levels of negative affect while driving. In a rational agent model – or one in which people make logically rational decisions (see Kahneman & Tversky, 1984 for an overview) – one would not expect differences between using a car for oneself or letting a child ride in it. Not surprisingly, this is not what we found. In contrast to the interest in use model, neither of the knowledge of self-driving cars variables was a significant predictor. Experience with advanced vehicle technologies also did not predict willingness to let an adolescent ride alone, but years of experience as a driver was significant. As years of driving experience increased, the likelihood of agreement decreased, controlling for other variables in the model. In this model gender and education also affected people's likelihood of agreement, controlling for other variables: women were less likely to agree; and as people's levels of education increased, they were less likely to agree to let an adolescent ride alone. Thus, when it came to a decision about letting a child ride in a self-driving car alone, risk and benefit perceptions, trust and negative affect were all significant, but women and people with higher levels of education tended to be more cautious than in the use case for themselves.

4.4. Limitations

Due to the cross-sectional study design, we cannot examine how people's opinions and judgments change over time or in response to new information about self-driving cars or experiences with advanced vehicle technologies. We can only examine the direction and magnitude of relationships of the self-reported measures we have in the sample. The model in Table III explained a relatively small amount of variance in the risk perception variable, particularly compared to the benefit perception and trust variables. The inclusion of additional other predictors may be essential to explain and understand what shapes people's risk perceptions of self-driving cars. One such variable that could be key to include is social trust. In this study trust was measured as trust in technology performance rather than trust in technology producers (i.e., social trust). While both types of trust matter for people's perceptions, social trust has been identified as an important predictor of risk and benefit perceptions and ultimately acceptance of new technologies (Siegrist, 1999; Siegrist & Cvetkovich, 2000; Siegrist, Cousin, Kastenholz, & Wiek, 2007; Siegrist, Cvetkovich, & Roth, 2000). Considering social trust may improve the prediction of trust in performance, benefit and in particular risk perceptions when affect has already been considered (Siegrist, Earle, & Gutscher, 2003). Another variable that may influence risk perception is negative media coverage around self-driving cars. Having heard of accidents related to self-driving cars did negatively influence trust in them, but not participants' risk perception. However, future research may consider studying media coverage in a

more nuanced way, as most people's current knowledge of self-driving cars comes from the media, which often portray the technology negatively by focusing on risks rather than benefits and reporting extensively and dramatically about accidents and legal or ethical issues (e.g., Borchers, 2013; Goidel & Langley, 1995). Significant media coverage with affect-laden images and stories also makes events like accidents more vivid and easily available in people's minds, which in turn can increase people's perceptions of risk (Raue & Scholl, 2018; Tversky & Kahneman, 1974).

Furthermore, there are some limitations and cautions around using the PANAS and global measures of affect generally, despite the use of the PANAS in prior studies on technology acceptance. First, in this study we focus on affect around "driving" but use these measures to explore people's judgments around a new driving technology. While we demonstrate the impact of these affective responses, people's affect toward the experience of driving may differ from their affect around current vehicle technologies, which may also differ from their affect toward self-driving cars in particular. Second, particular emotional reactions may be more powerful in understanding risk and benefit perceptions, trust in and adoption of new technologies. Some of the so-called basic emotions – such as anger and fear – are absent from the usual PANAS inventory, but they may be important when it comes to technology adoption. For example, fear of a new technology or anger with a current technology may be powerful motivators around acceptance (see Lerner & Keltner, 2001 for the influence of fear and anger on risk perception). Future work should explore how some of these individual emotions, as well as more global affective assessments, contribute to risk and benefit perceptions and to acceptance.

4.5 Conclusions

In this study we found evidence that affect related to regular driving influences people's perceptions and acceptance of self-driving cars. Self-driving cars are a new technology, and relatively few people have had any direct experience with it at this point. Although subjective knowledge of and experience with advanced vehicle technologies were significant predictors of perceptions of and interest in using self-driving cars, our results illustrate how affect around the experience of using a similar technology – driving current vehicles – might shape people's assessments of a new technology. In the case of self-driving cars and new technologies more generally, our results suggest that it may be important to consider whether and in what ways these technologies disrupt individuals' senses of autonomy and control. Giving up control may, in fact, be one of the major barriers to the adoption of self-driving cars (Abraham et al., 2018; Howard & Dai, 2013; Kyriakidis et al., 2015). As technologies and automated systems continue to take on tasks once reserved for humans, understanding how people make judgments about them, and how these judgments affect their acceptance and use, will become increasingly important.

Our results further underscore the significance of benefit perception for understanding technology acceptance. As self-driving cars are still more conceptual than tangible, their usefulness may not be obvious to many, but so too may the risks of such technologies not be fully understood. As the technology continues to mature and become more widely adopted, it may be especially important to communicate to the public about its benefits and risks, so that communities can make better decisions about how they want to use and interact with the technology.

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APPENDIX

Table A1. Variable: Confidence in driving skills

Variable	Item Wording	Response Options	<i>M (SD)</i>
Confidence in driving skills	How confident do you feel about your ability to do each of the following?	From 1 (not at all confident) to 5 (very confident)	4.39 (0.62)
	- React quickly to a change in the environment by steering to avoid a crash		
	- Maintain driving at the speed of traffic while traveling on a highway		
	- Scan an intersection to make sure that it is safe to drive through it		
	- Reverse a vehicle in a straight line		
	- While driving in traffic, change into a right-hand lane		
	- React quickly to a change in the environment by braking suddenly		
	- Parallel park between two vehicles		
	- While driving in traffic, change into a left-hand lane		
	- Physically turn around to reverse a vehicle		
$\alpha = .88$			

Table A2. Correlations of all variables

	1	2	3	4	5	6	7	8	9	10	11
1 Self-reported knowledge of self-driving cars											
2 Experience with advanced vehicle technologies		.42**									
3 Years as a driver			-.31**								

4	Driving frequency	.15**	.21**	-.15**									
5	Positive affect - enjoyment	.26**	.46**	-.14**	.17**								
6	Positive affect - control	0.01	-0.03	.17**	-0.03	.31**							
7	Negative affect	.22**	.29**	-.38**	0.03	.14**	-.20**						
8	Risk perception	-.09**	-.10**	.07**	-0.005	-0.01	.07**	0.02					
9	Benefit perception	.37**	.35**	-.30**	.09**	.25**	-.06*	.22**	-.46**				
10	Trust in self-driving cars	.38**	.43**	-.28**	.13**	.27**	-0.05	.21**	-.49**	.64**			
11	Interest in self-driving cars	.45**	.43**	-.39**	.11**	.28**	-.08**	.28**	-.44**	.80**	.69**		
12	Confidence in driving skills	.06*	0.05	.21**	.14**	.18**	.38**	-.31**	.08**	-.08**	-0.03	-.08**	

* $p < .05$, ** $p < .01$.

$N = 1484$

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