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Incorrect Beliefs about Start/Stop Ignition Systems in Automotive Vehicles

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This research examines knowledge and awareness of aspects associated with completely electronic ignition systems (with start/stop buttons) in internal-combustion vehicle engines. A scenario was presented to participants where the start/stop button is not depressed to turn off the engine before leaving their vehicle in a garage. Open-ended responses showed that some people had some basic knowledge about what could happen in this scenario, but many people did not. The results suggest that many people have incorrect or incomplete knowledge about how these systems work. Most do not mention the severe consequences of inadvertently failing to press the engine button before exiting a vehicle in an enclosed environment, i.e., the build up of carbon monoxide. Many participants believed the vehicle would give a warning or turn off by itself after a period of time. Implications for design-engineering solutions and multi-modal warnings are discussed.

Practitioner Summary: Vehicle ignition systems are being made "easy to use" but violate principles of HFE that would avoid foreseeable and dangerous happenstances. Inadvertent failure to press the start/stop button on completely electronic key systems in enclosed environments, such as residential garages could lead to carbon monoxide poisoning. Manufacturers and government regulators should consider having more safeguards to prevent these and other hazardous consequences of completely electronic key systems.

Keywords: vehicle, key, ignition, carbon monoxide, omission

1. Introduction

Human factors and ergonomics (HFE) researchers have studied factors associated with people's beliefs regarding numerous safety-related automotive vehicle issues. Research shows drivers' and passengers' beliefs on proper vehicle functioning, maintenance, and safety frequently do not comport with manufacturer's recommendations (e.g., as advised in owners' manuals). Shaver and Wogalter (2001) showed that people had incorrect beliefs about the safety limitations of early versions of airbags with respect to children and small statured adults. Other research shows bias in attributions depending on category assignment of people and vehicle types, e.g., (a) drivers vs. non-drivers of SUVs (Mayhorn, Wogalter, and Conzola, 2010), and (b) drivers of farm equipment on the roads vs. non-drivers of those vehicles (Costello and Wogalter, 2003). Furthermore, research has also shown that drivers underestimate vehicle maintenance needs and overestimate the timing of maintenance procedures needed to maintain proper vehicle functioning and safety. Research indicates drivers lack important knowledge on tire maintenance (e.g., Mayer and Laux, 1990; Starch, 1999) that could reduce the risk of tire failure and the potential consequence – loss of control. Many drivers lack knowledge on how and when to determine tire inflation pressure. Kalsher, Wogalter, Lim, and Laughery (2005) reported that drivers overestimate tire lifespans and the duration of which spare tires could be safely stored in trunks (see also, Cowley, Kim, and Wogalter, 2006). They also do not know how to use the date of manufacture embossed on a tire sidewall to determine the tire's age (Taylor & Wogalter, 2011). Thus, when looking at research across several domains, there are indications that drivers and passengers are at least somewhat misinformed about several vehicle safety-related aspects.

One area that has not received much research is drivers' perceptions regarding a recent technological and functional change to vehicle ignition systems. These are completely electronic key systems (CEKS) with start/stop buttons. These systems are in contrast with traditional mechanical key systems (MEKS) and semi-automatic key systems (mechanical key with an electronic fob controlling the locks and windows, or SAKS). The present work is a preliminary study of people's beliefs associated with CEKS. In particular, we sought to determine if there are incorrect beliefs that could lead to dangerous circumstances.

Until recently, most vehicles were manufactured with MEKS, resulting in most drivers being accustomed to these types of systems. After many years of experience with MEKS, the acts involved in starting up, driving, and turning off vehicles have become behaviorally-automated such that individual acts have become a cluster of acts that are easily and reliably performed without much thought or consciousness (e.g., Norman, 1981; Reason, 1990). With the newer ignition systems such as CEKS, some behaviors are different than those involved with mechanical or semi-automatic keys. Until recently, vehicle ignition keys were completely mechanical but electronic functions have been added, and fobs without any mechanical aspect are becoming standard equipment.

SAKS and CEKS have benefits such as remotely opening trunks and locking doors. Vehicles with CEKS are started by pressing a Start/Stop Engine button (SSEB) (while stepping on the brake) without having to insert and turn a key. To stop a CEKS's engine, the driver needs to press the same button without having to turn and remove a key. While the start/stop button may seem easy to use and would seem to be an improvement over the MEKS, CEKS have some aspects of added risk that are counter to safety by enabling certain kinds of anticipatable human error. These are omission-type errors where people fail to do a task that they normally would do, such as pressing a button to turn off a vehicle. Omission errors can occur in numerous scenarios including when there is task interruption that breaks into the clustered sequence of tasks, resulting in not performing a critical task. It is foreseeable that routines (as in starting up or powering down a vehicle) can be interrupted by a whole host unexpected or novel occurrences. People can fail to recognize that steps have been skipped (Norman, 1981). An example of a task causing interference with a routine task is an unexpected cell phone ring or an emotionally laden phone conversation or a child spilling ice cream in the back seat at critical times. Because of interruptions, drivers may forget to turn off the vehicle engine or not realize that they did not turn off the engine. Procedures with mechanical keys—although similar, are somewhat different and provide different external cues. Once drivers' notice the keys are not in their possession, they might trace their actions back to their vehicle. CEKS do not offer the same kind of cues.

One potential problem with CEKS is people may inadvertently fail to press the stop button before leaving the vehicle. While people may inadvertently leave a mechanically-keyed vehicle running, there is a difference with the CEKS in the off mode: If the mechanical (or semi-electronic) key is with you (located some distance away from the vehicle), then you know the vehicle must be off. However, this is not necessarily true with CEKS. The inadvertent failure to press the SSEB may occur for several reasons, including exiting quickly due to emergency or being distracted by a conversation. With many vehicles engineered to run quietly, drivers may not realize their vehicles are still running (Wogalter, Nyeste & Lim, 2014). Some vehicles left running give a sound or a sequence of sounds when the fob is brought outside of the vehicle or beyond some perimeter distance away. Usually these warning sounds are often not loud and are similar to sounds used for other functions (e.g., beeps when locking or unlocking doors). For vehicles parked in home garages, the sounds could be masked by the garage door closing or not heard by persons with hearing loss.

Leaving the vehicle running or "on" can lead to negative outcomes. One kind of negative outcome relates to the occurrence of a vehicle left running inside a confined space (e.g., garage). Deadly carbon monoxide (CO) can build up over time. Some deaths in the U.S. have been attributed to CO traveling inside homes and poisoning the occupants.

The present study examined whether people realize this particular potential problem with the CEKS. As a first study on this topic, it was explored using open-ended questioning. A scenario involving CEKS was given and participants described what they thought would happen. These reports were analyzed by categorizing the main kinds of content that appeared in the responses to determine if there were any systematic errors in the participants' assumptions and beliefs.

2. Method

2.1 Participants.

Comprising the total number of 94 participants (33 males and 61 females) were two groups: (a) 62 university students from a large public land-grant university in the southeast United States (*M*=20.1 years, *SD*=1.6) who received research credit in their introductory psychology courses, and (b) 31 nonstudent adults (*M*=44.7 years, *SD*=16.4) from various surrounding locales in North Carolina who volunteered to participate without remuneration.

2.2 Procedure.

Participants were given a scenario to read carefully before responding.

> **"**Suppose that you are running late for an important television program. Imagine that you drive your recently-purchased vehicle into your garage and close the garage door. You put the vehicle in the P for 'Park' gear. In your rush out, you forget to depress the engine button (shown below in Figure 1) to turn off the engine**.** You open the vehicle door and exit the vehicle. You close the door and go inside the house. The key fob (shown below in Figure 1) is in your pocket. Describe what you believe might happen with the vehicle if you were to leave it that way. Please write a description in as much detail as you can in the space below."

Figure 1. Pictures shown with scenario: Engine ignition button (shown on left side) and key fob (shown on right side).

Thus, the scenario asked participants to assume they were in a rush, and when exiting the vehicle in their garage they do not depress the start/stop engine button—leaving the vehicle running and taking the key fob with them into the house. Participants are then instructed to describe what they believe would happen if the vehicle were left in that condition. These open-ended responses were subsequently transcribed and categorized into semantically-related groupings.

3. Results

To summarize the open-ended responses, narrative responses were categorized into semantically related groupings. These groupings are shown in Table 1. There were more responses (a total of 120) than participants (N=94) because some of the participants' answers were applicable to more than one category.

The reports given by participants appeared to best fit 8 categories with a ninth category "other". The results show that about 63% of participants correctly noted that the vehicle would continue to run in the circumstances described. Also 19 responses (20%) correctly mentioned carbon monoxide (CO) or exhaust as a problem—the scenario's main danger in an enclosed garage. However, there were another 19 responses (20%) that indicated that the vehicle would automatically turn off due to the fob being out of range. This is incorrect at least in U.S. vehicles. Several participants also mentioned that the vehicle would turn off after a length of time (n=4), after a warning (n=2), or that functions would be disabled (n=5), all of which are incorrect answers.

Table 1. Responses (frequencies and percentages) according to Category (ordered high to low frequency (*f*)).

Response Category	**Response (*f*)**	**Percent (%)**
Engine continues running	59	62.77
Engine shuts off when fob out of range	19	20.21
Exhaust (CO) could cause illness/death	19	20.21
Vehicle emits warning but keeps running	7	7.44
Vehicle will disable features	5	5.32
Engine shuts off after certain time	4	4.26
Other	3	3.20
Vehicle emits warning and shuts off	2	2.13
Key fob warns that car is running	2	2.13

Note: 120 total responses from N=94 participants.

4. Discussion

Few people have much knowledge about the operation of CEKS. However, one example of people having some knowledge is the finding that 63% of the participants reporting in their response that the engine continues running in the described scenario. Also demonstrating some correct knowledge is mention of a carbon monoxide (CO) poisoning risk. However, the level of report is not high, only 20% mention it as a potential consequence of the scenario.

There is further evidence that participants are not well versed in the possible consequences and risks present in the scenario; the evidence is shown in the frequencies of participants' responses found in the other categories listed. One set of responses was 20% of participants stating (incorrectly) that the engine shuts off when the fob is out of range. This is a serious error as people may believe that they do not need to return to their vehicle if they suspect that they failed to turn off their vehicle. The presence of the fob in your hand inside of your house does not provide any information on whether your car is off or still on (in current implementations of CEKS). However, the presence of the key in older mechanical key systems (MEKS and SAKS) with you when away from the vehicle indicates the vehicle is off (unless someone else has keys or a spare key is being used). Users need to know the current CEKS vehicles' engines do not turn off by themselves (and sometimes may idle for many hours) except when they runs out of gas or when oxygen is depleted. Incorrect beliefs about this could result in a decreased level cautiousness that does not match with actual risk/hazard. The task of noticing that the engine is still on is made even more difficult by its use in very quiet vehicles being produced by manufacturers (Wogalter et al., 2014).

Unfortunately while appearing simple, CEKS's operations and associated dangers are not transparent or intuitive. While arguably fully automatic systems look easy to use (and marketed as a selling point), they have operations and consequences of their use that people do not understand. Thus expected inadvertent errors could result in serious injury or death (Leonard & Wogalter, 2000). Traditional mechanical key systems (MEKS and SAKS) have aspects that provide more cues, such as not being able to pull out the key if the engine is not turned to off.

One way to deal with the negative effects of leaving vehicles running and avoid the negative consequences of CO poisoning is by using effective warnings to alert drivers who have inadvertently left their vehicles running. Some manufacturers include sounds outside the car to alert drivers that the fob is outside the vehicle when the engine is still on. Some current sounds are less urgent than the hazard, and some manufacturers give no sound cues at all in this situation. Appropriate warnings can include visual cues such as flashing lights and a sufficiently loud, distinguishable auditory alert (with at least adequate dBs over other environmental sounds such as garage doors closing) that is not used for any other vehicle function (to attract attention).

In addition, as a backup, the vehicle could shut off before CO builds up to dangerous levels, either through a system that detects exhaust fumes/vapors or after some period of time after there is no movement detected inside the vehicle. More sophisticated systems would allow the engine to run when needed, such when the vehicle is being used as protection in a major weather event.

Most vehicle manufacturers are building vehicles that run very quietly. However, research shows that drivers prefer at least some audible engine sound (Wogalter et al., 2014) in part to facilitate drivers' and pedestrians' judgments about vehicle speed and movement. That work and the current study suggest that very quiet engines reduce the auditory cues that indicate the engine is (still) on. It enhances the likelihood of the omission-type error involving the "stop" button.

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