THINKING ABOUT DISTRACTION – A CONCEPTUAL FRAMEWORK FOR ASSESSING DRIVER-VEHICLE ON-ROAD PERFORMANCE IN RELATION TO SECONDARY TASK ACTIVITY

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ABSTRACT

Recently, the relationship between driver distraction and road safety has come strongly into focus, based on findings presented from Naturalistic Driving Studies and Field Operational Tests.

Reviews of current literature on the subject show that the available conceptual frameworks for describing the relationship between secondary task involvement and driver performance are predominantly linear and mono-dimensional, i.e. they propose a single, direct and linear correlation between secondary task engagement and reduction in driver performance. However, as research into other areas of human performance show, descriptions of a linear and/or mono-dimensional character rarely are sufficient to predict the differences between mono- and multitasking in human operators.

Transferred to automotive safety, this means that to evaluate the effects of new in-vehicle systems on driver performance, a more sophisticated framework is needed. In particular, any warning/intervention capabilities of the vehicle, the current performance capacity of the driver, and primary task demand variation all need to be added and accounted for in order to accurately assess the extent to which secondary task involvement may degrade primary task performance.

In this paper, a conceptual framework which takes these additional dimensions into account is outlined. The framework describes how driver performance capacity, the availability of active safety systems in the vehicle and the current demands from the traffic environment should be jointly considered in relation to the effects on driver performance of secondary task engagement. Based on this, general areas where improvements can be made in order to mitigate negative consequences of non-driving tasks are presented.

INTRODUCTION

Driver distraction is widely recognized as a significant road safety issue[1][2]. Numerous studies point to distraction as an important underlying reason for why drivers get involved in crashes. For example, the U.S. Department of Transportation's analysis of several crash databases suggests that approximately 18-22% of crashes are associated with what they define as distracting activities [3].

These statistics seem clear enough, but when it comes to preventing distraction related crashes, it gets more complicated. First, there is the issue of defining what distraction is. In the NTHSA study [3], distraction is defined in a wide and inclusive sense, focusing on what they identify as sources of distraction. These include phoning, eating, reading, personal hygiene, reaching for objects in the vehicle, etc, i.e. any non-driving related activity the driver was involved in when the crash occurred.

However, if one looks at the general prevalence of such non-driving related activities, Stutts et al [4] found that of the total driving time, drivers spent approximately 15.3 % engaged in conversation with passengers and 14.5 % doing some other activity. Sayer et al [5] found that drivers engage in some secondary tasks 34 % of total driving time, with conversation with another passenger as the most frequent (15 %), followed by grooming (6.5%), use of a hand-held cellular phone (5.3%), and eating or drinking (1.9%). Finally, Klauer, et al. [6] found that drivers engaged in secondary tasks 23.5 % of the time that they were driving.

Taken together with the NHTSA study on crashes involving distraction, these numbers suggest an interesting picture. At face value, the simplest interpretation would be that non-driving related activities should be viewed as a form of exposure, rather than as reasons for why crashes occur. Put differently, the numbers in [3] on drivers doing non-driving related tasks when crashing are exactly what one would expect, given the prevalence of secondary task engagement in ordinary driving identified by the naturalistic driving studies. In fact, if non-driving related activities take up ~25-30 % of the total driving time and crash databases show such activities to be associated with only 18-22 % of all crashes, there is either a real underreporting problem, or non-driving related tasks may actually have a protective effect (the relative risk of a crash is higher for drivers not doing secondary tasks).

It follows that not all non-driving related tasks can automatically be classified as distractions, in the sense that performing them increases the risk of being involved in a crash. While underreporting certainly is an issue in this area, the numbers suggest the effects of non-driving related tasks cannot be conceptualized as a direct, linear correlation between secondary task engagement and reduction in driver performance. Instead, to understand how non-driving related tasks may compromise driver performance, a more nuanced description of the underlying mechanisms is required.

One way to approach this challenge is to start with the analysis of the data from the 100 car naturalistic driving study performed by Guo & Hankey [7]. When looking at the effect of non-driving related tasks, they differentiated between three levels of secondary task complexity, based on definitions of manual-visual complexity in Dingus et al [8], as shown in Table 1. In this classification, simple secondary tasks require, at most, one button press or eye glance away from the forward roadway. A moderate secondary task require one to two button presses and/or eye glances away from the forward roadway, while complex secondary tasks require more than two button presses and/or eye glances away from the forward roadway.

Given this definition, Guo & Hankey [7] found that only complex tasks (e.g. dialing a handheld device) increased crash risk. Simple and moderately complex secondary tasks (e.g. eating, drinking, talking to a passenger) on the other hand actually showed a protective effect, i.e. the risk of being involved in a crash or near crash decreased when drivers performed these activities. Engaging in simple and moderately complex secondary tasks thus seems to be better than doing nothing at all, while engaging in complex tasks get people into trouble.

The most straightforward interpretation of these results is that doing something else while driving actually improves how well you drive ,at least in terms of avoiding near crashes and crashes, up to a certain level of task complexity, where the capacity to drive safely instead becomes compromised by concurrent activity involvement. To understand how and why this can be the case, two further explanatory dimensions that characterize human behavior and performance need to be introduced, namely *arousal* and *adaptivity*. The concept of arousal, here understood as the level of activation/excitation in the driver, can be used to explain why simple and moderately complex tasks improve driving performance, while conceptualizing driving as a continuous adaptive process helps explain why complex tasks lead to increased crash and near crash risk.

Table 1: Assignment of secondary tasks to three levels of manual-visual complexity

	Simple	Moderate	Complex
1	Adjusting Radio	Talking / Listening to handheld device	Dialing a handheld device
2	Adjusting other devices integral to the vehicle	Handheld device other	Locating / reaching / answering a handheld device
3	Talking to passenger in adjacent seat	Inserting /retrieving CD	Operating a personal digital assistant (PDA)
4	Talking/Singing: no passenger present	Inserting / retrieving cassette	Viewing a PDA
5	Drinking	Reaching for object (not handheld device)	Reading
6	Smoking	Combing or fixing hair	Animal / object in vehicle
7	Lost in thought	Other personal hygiene	Reaching for a moving object
8	Other simple tasks	Eating	Insect in vehicle
9		Looking at external object	Applying makeup

AROUSAL

In many disciplines, from toxicology, enzymology and biomedicine to experimental psychology, one of the most fundamental mechanisms describing how well an organism performs is what generally can be referred to as hormesis, or the dose-response concept [9]. In experimental psychology, the phenomenon goes under the name of the Yerkes-Dodson law (most famously described by Broadhurst [10]). The Yerkes-Dodson law is a dose-response description of the relationship of stress to performance under varying degrees of task complexity/difficulty.

The original Yerkes-Dodson law essentially stated that a high level of motivation can enhance learning on an easy task and impair learning on a difficult task. Put differently, performance on simple tasks is continuously improved when arousal increases (linear relationship), while for more complex and difficult tasks, the initial improvement reaches a peak at some level of arousal, and then decreases as arousal continues to decrease (curvilinear relationship). also, the more difficult the task, the earlier (or more to the left) comes peak performance, i.e. the level of arousal for optimal performance decreases with increased task complexity.
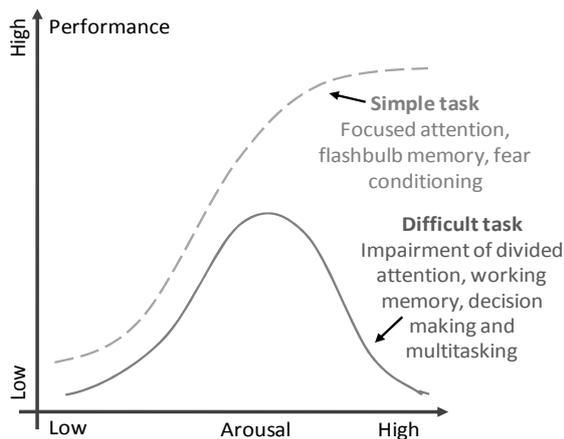
Figure 1: Illustration of original Yerkes-Dodson law, adapted from [12].

This law has been validated for motor complexity, i.e. if the task requires fine motor skill, the optimal level of arousal is low, while if the task only requires gross motor skill, the optimal level of arousal is high [11]. It also seems to cover cognition in an interesting way, i.e. if the successful completion of a task requires involvement of the Pre-Frontal Cortex (PFC), then performance on that task is likely to suffer under conditions of high arousal [12]. For example, high states of anxiety have little or no effect on performance in simple, single-digit, mental calculations, which place minimal demands on PFC based working memory capacity. On the other hand people who perform more complex mental math, such as double-digit calculations which require more working memory and thus increased PFC involvement, are more susceptible to impairment by anxiety [13]. Notably, even the single-digit calculations were susceptible to impairment by anxiety if a PFC-dependent component, such as decision-making, was included in the calculations [13].

AROUSAL - IMPLICATIONS FOR DRIVING

The Yerkes-Dodson law offers a partial explanation of the results in [7]. Driving, in the sense of maneuvering at normal speeds, is fairly reminiscent of walking. In terms of how Guo & Hankey classified task complexity, driving a vehicle would be considered a simple task, like for example drinking from a bottle, i.e. it is an overlearned, highly automated task that does not require a dedicated PFC component or motor control effort.

It follows that performance in terms of vehicle maneuvering alone can be expected to follow the level of arousal in the linear rather than the curvilinear fashion depicted above in Fig 1**,** i.e. the more aroused or engaged the driver is, the better the vehicle control will be. It also follows that the task of just maneuvering the vehicle will not lead to

increased arousal, in the sense that it that would lead to general driving performance improvement in terms of avoiding crashes and near crashes. To make that happen, some other condition which stresses, or arouses, the biological system (the driver) is necessary.

According to the findings of Guo & Hankey, secondary tasks appear to be able to take on this stressor role. When simple and moderately complex secondary tasks are added to the driving task, arousal increases in a way which results in overall better driving performance. However, when the added tasks go beyond a certain level of complexity, driving performance starts to decrease and eventually goes below the level of performance that can be expected for just driving under low arousal.

The Yerkes-Dodson law can also be applied to other stressors than non-driving related tasks, such as when there is a difficult traffic situation to negotiate or when the driver is trying to win a race. Here the difficulty of negotiation the external situation drives an increased arousal in the driver, which in turn leads to improved driving performance up to the point where the driver reaches his/her performance limits (i.e. even if you want to win the race and stay absolutely focused, you may loose to a more skilled driver). This roughly corresponds to the peak performance metaphor in sports, i.e. the coach wants the players to be sufficiently aroused to perform at their best, but not overly aroused because then they start making mistakes.

The Yerkes-Dodson law also explains situations where stress or arousal is self induced, e.g. when a really tired driver starts talking to himself to avoid falling asleep. In fact, one way of explaining why truck drivers show less risk of crash or near crash involvement when using CB radio [7] could be on exactly these lines; when tired or drowsy the driver calls up a friend and starts up a conversation in order to increase his own alertness.

However, while the Yerkes-Dodson law can be used to explain why simple and moderately complex tasks improve driving performance, it does not account for why complex tasks lead to increased crash risk. The reason for this is that engaging in secondary, non-driving related tasks while driving is largely a self paced activity. In other words, the driver chooses when, where and for how long s/he should do it, as well as how to time-share between that and the driving task.

Given that drivers generally do not want to crash, it follows that there must exist a mechanism by which complex tasks, but not simple or moderately complex tasks, compromise the driver's capacity to judge when, and to what extent s/he should engage in that task. To understand what this mechanism might look like, it is first necessary to

put forward a general understanding of driving and the driver's role in it.

ADAPTIVITY

One way of viewing driving is as a control task which involves continuous adaptation in the face of a changing environment, in a way which promotes goal fulfillment [14]. Control can be generally defined as the ability to direct and manage the development of events [15] , or more specifically the maintenance of one or more goal states in face of disturbances [14].

In engineering control theory, a goal state is often called the reference, or target, value. To describe how drivers set these target values, Näätänen & Summala [16] proposed the zero-risk theory. The theory says that driver behavior can be understood as a balancing act between excitatory "forces" that represent a motivation for the driver to actively seek and exploit opportunities for action present in the environment (such as looking for a gap to overtake in), and inhibitory forces, originally proposed as based on experiences of subjective risk, and driven by a desire to avoid such risk completely.

Vaa [17] recently developed this idea further by incorporating Damasio's concept of *somatic markers* [18], i.e. emotional signals that attach positive or negative values to possible action choices, based on the outcome of making similar choices in the past. Vaa states that adaptive driver behavior largely is governed by such somatic markers, i.e. the driver experiences unpleasant feelings in response to threatening situations and acts accordingly. Building on this, Summala [19] proposed a modified zero–risk model where the driver strives to maintain a state of zero discomfort rather than zero subjective risk.

The way drivers select reference values for the control tasks can thus be viewed as a balance act between a desire for goal fulfillment and discomfort avoidance. The result is adaptive driver behavior, where drivers respond to changes in driving demand (current and predicted) by selecting reference values that will result in goal fulfillment without generating feelings of discomfort.

In more general terms, drivers principally seek goal states which they believe are within a safety zone [19]. Also, to maintain the state of zero discomfort, drivers generally prefer goal states with a certain minimum distance, or safety margin, to the safety zone boundary. This can be conceptualized as a comfort zone, i.e. a region of reference values for which no discomfort is felt or predicted by the driver, and which the driver therefore prefers to stay within. If the comfort zone boundary is exceeded, a feeling of discomfort will be experienced, resulting in adaptive behavior in terms of corrective actions [19][20].

Figure 2: Illustration of driver adapting speed to comfort zone boundary in face of changing friction conditions (adapted from [19]).

In this example, the driver successfully perceives the change in safety zone boundary which occurs when friction is reduced due to for example a sudden snowfall. Since the current speed feels uncomfortable in relation to this change in conditions, the driver adapts by slowing down to a speed well below the safety zone boundary for the new friction conditions, and manages to do so without exiting the comfort zone. The driver thus avoids feelings of discomfort as well as loss of control.

Successful adaptation and, hence, maintenance of control, depends on several factors. One is an accurate estimation of the safety zone boundary. This includes accurate perception of variables which specify the physical limits for action, such as road geometry, presence of other road users, friction, etc., but also relies on general information (e.g. from a traffic information service) and previously acquired world knowledge (e.g. roads may become extra slippery in shaded areas after night frost).

Another key factor that governs successful adaptation is expectancy. In general, drivers adapt their goal states not only based on what the current situation looks like, but also on how they expect it to unfold. In particular, expectancy determines drivers' anticipatory visual search and attention allocation strategies [21][22][23]. Expectancy is supported both by perception of the current driving situation (position of other vehicles, etc) as well as by previous knowledge and experience of traffic environment properties and road user behavior.

A third factor is the way in which drivers update their estimate of the safety zone boundary. In engineering, control is discussed in terms of optimization, with the aim of minimizing any deviation from intended goal states. However, human control seems to follow another principle. The reason is that maintaining control requires effort, and people are generally unwilling to invest more than the perceived necessary effort to reach a satisfactory level of control performance. Since

optimal performance usually requires more effort than doing something "good enough", people tend to trade off performance against effort in order to preserve energy [24]. This type of control can be called satisficing control, and represents a form of energy conservation. Satisficing can be regarded as the normal mode of operation in everyday driving [25][26][19], as well as in human decision making in general [27][28].

One implication for driving is that drivers will reassess where they are in relation to the safety zone boundary in a satisficing rather than an optimizing way. For example, when driving on a wide motorway in sparse traffic there is little motivation to stay exactly in the middle of the lane. The driver may therefore tolerate some lane drift rather than attempt to keep the vehicle precisely at lane centre. In this condition, tracking and adjusting to the lane markers can be an intermittent rather than continuous activity, something which frees up time and resources for doing something else, should the driver be motivated to do so.

ADAPTIVITY - IMPLICATIONS FOR SAFE DRIVING

A key element in the relationship between driving and non-driving related tasks is time-sharing, i.e. how the drivers partition their time between the two tasks. If driving is conceptualized as a continuous adaptive process where drivers strive to stay within the comfort zone, then driving while doing something else can be characterised as a process where the driver continuously shifts between doing the other task and reassessing the safety zone boundary. Based on this view, one way of understanding how complex tasks may compromise safety is that they at times are able to disturb the reassessment of the safety zone boundary, either by prolonging the time between assessments so much that what goes on outside the vehicle changes significantly more than the driver expects, or by compromising the actual boundary assessment.

The ability of complex tasks to disturb reassessment of the safety zone boundary probably is due to a combination of emotional, cognitive and visual-motor components. Of these, the visual-motor component is perhaps the most obvious and immediately comprehensible (in fact, it actually corresponds to the definition of task complexity above [8]). If the driver has to look somewhere else than on the road to continue with a task, e.g. to read from a display or to coordinate hand/finger movements to press buttons on a handheld device, the time it takes to complete that visual-motor task will be a key determinant for the time between safety zone boundary re-assessments, i.e. looking back on the road and re-evaluating the driving situation.

Emotional components are also relatively easy to picture. In Näätänen & Summala's original model [16], they are offered in terms of what they call *extra motives*. In relation to the comfort zone for driving described above, they predict that the feelings of discomfort induced by driving outside the "normal" comfort zone sometimes can be suppressed or outweighed by feelings related to *extra motives*. These motives typically come in the form of strong emotions, such as anger directed at a slow lead vehicle when short on time, a deep desire to impress co-travellers or the sensual pleasure of travelling at high speed [16].

However, extra motives can also be expected for non-driving related tasks. For example, when communicating with other people, sending time critical messages ("I'm running late, so you need to pick up the kids from school!") might provide such an extra motive. When extra motives drive the performance of non-driving related tasks, these may become prioritized at the cost of the normal reassessment of the safety zone boundary, thus either delaying the assessment and/or reducing its accuracy.

In terms of cognitive components, Diamond et al suggest that in general, tasks that require the involvement of the pre-frontal cortex (PFC), should all exhibit the curvilinear rather than the linear component of the Yerkes-Dodson law [12]. In other words, one way of operationalizing the distinction between "simple" and "complex" tasks is to determine to what extent they involve a PFC mediated component. This is not directly applicable to Guo & Hankey's results [7], as the separation of tasks they use is based on manual-visual complexity rather than PFC involvement. For example, talking to a passenger is listed as a simple task, though that would (hopefully) be a clear sign of PFC involvement.

However, another way of conceptualizing the effect of cognitive load is as potentially contributing to quality degradation in the comfort zone boundary reassessment. Support for this idea comes from several recent studies which have found that drivers who do cognitive tasks respond slower to cued events. For example, drivers without cognitive loading respond faster to a braking lead vehicle if the braking is cued by an event further down the road, such as a pedestrian crossing the road, than when there is no apparent reason for the braking. Drivers doing a working memory task on the other hand respond as if the lead vehicle was braking for no apparent reason in both situations [30] [31].

Thus, while looking away from the forward roadway at the same time as something unexpected happens may be the key mechanism underlying critical events [32][24], one must not forget that an underlying reason for looking away in the first

place may be a sub-standard assessment of the safety zone boundary (i.e. whether it is a good time to look away), due to cognitive load.

A NEW FRAMEWORK FOR UNDERSTANDING DISTRACTION AND ITS IMPLICATIONS FOR VEHICLE DESIGN

One assumption underlying the current debate on distraction is that distraction causes crashes. As the above discussion on the extent to which drivers engage in non-driving related activities shows, this represents an overly simplistic representation of the challenges of driving and how drivers cope with them. To understand how non-driving related tasks effect the risk of crash involvement, further performance shaping dimensions are necessary to include. First and foremost, the non-linear coupling between arousal and task complexity needs to be accounted for, i.e. one must integrate the realization that driving performance inherently depends on both the level of arousal as well as on the level of total task complexity.

One way such a new framework can be conceptualized is illustrated in Figure 3. Here the area of sufficiently high driving performance is conceptualized as a performance comfort zone, wedged between the states of insufficient driver arousal and too high total task complexity (i.e. the demand of driving and non-driving tasks combined).
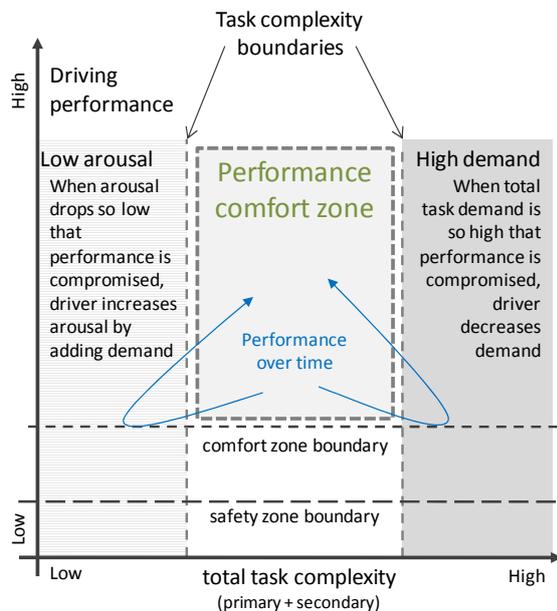
Figure 3: Driver adaptively staying in the performance comfort zone by adding demand when arousal is low and removing demand when complexity is high.

In terms of the discussion on arousal and adaptivity above, drivers in this framework are viewed as actors which proactively keep themselves in this performance comfort zone by adjusting total task complexity when approaching the performance comfort zone boundaries. When they feel their driving performance become too low (e.g. the driver is tired), and the driving task itself is too simple to maintain a sufficient level of arousal to keep performance up (.e.g. sparse traffic, monotonous road), they add one or more non-driving related tasks to increase total task complexity (like talking over CB-radio), thereby increasing their arousal which in turn pushes the level of driving performance up. Reversely, in driving situations where total task demand becomes so high that they are pushed close to, or outside, the comfort zone boundary, they adjust by reducing total task complexity, for example by slowing down (reduced primary task complexity) and/or suspending the non-driving related task.

This way of conceptualizing the relationship between driving and non-driving tasks has several implications for future vehicle design. First, in terms of maintaining a sufficient level of arousal to keep driving performance within the comfort zone (and thus within the safety zone boundary), one implication is that the vehicle could be used to actively engage the driver in a situation where the driver's arousal level drops so low that primary task performance is compromised and the driver fails to self-adjust. Accomplishing this presents two technical challenges; how to detect low arousal and how to create an interaction with the driver that increases driver vigilance.

In terms of detecting low levels of arousal, several systems are already being deployed in the vehicle fleets. For example, Volvo Cars has developed Driver Alert Control, which essentially tracks lane keeping performance to a degradation level predictive of drivers about to fall asleep [33]. While the current suggestion from the system to the driver should s/he exceed a certain level of impairment is to take a break, more sophisticated methods of interaction once this level of impairment is detected could be suggested, to cover also those drivers who for some reason are either unable or unwilling to break their journey.

Second, given the framework above, the negative effects which complex tasks occasionally have can be conceptualized as a delay or a quality degradation in the driver's reassessment of the comfort zone boundary, leading to involuntary boundary crossings and late adjustments. This description is in line with findings on typical accident mechanisms from the 100 car study [32] [34], and it points to two key parameters when it comes to designing new in-vehicle tasks that would be defined as complex according to Dingus et al

[8]. These are time sharing and what can be called immersion resilience.

Time sharing refers to how the driver divides his/her attention between the primary and secondary task. In principle, any non-driving related task should be possible to perform without compromising the possibility of a frequent reassessment of the safety zone boundary, i.e. each cycle of interaction with the non-driving task needs to be kept shorter than a certain length of time. For example, the 100 car study showed that the risk of risk of crash and near crash involvement was significantly higher for drivers who looked away from the forward roadway for more than 2 seconds within a 6 second time frame prior to the event [34], compared to looking away less than 2 seconds. This means that if each step of a non-driving task can be accomplished within say 1.5 seconds, the effect on crash risk of performing that task would probably be the same as when talking to a passenger, i.e. incident/crash risk remains neutral or decreases.

Immersion resilience refers to the need to avoid a situation where the secondary task in practice becomes the primary task, i.e. the non-driving task takes performance priority over driving. In the field of computer game design, the literature is rich with examples of how to enhance a player's level of immersion in a game (e.g. a simple search in the Science Direct-database on the keywords "game immersion" yields 2837 hits). However, in terms of in-vehicle task design, all findings on how to make the players "forget" the immediate surroundings and drag them into the game can essentially be viewed as an errata list, i.e. design features one need to implement differently in order to let the driver at all times prioritize the primary task. Accomplishing this is of course less straightforward than keeping interaction cycles short. However, one direct implication for evaluation is that when measuring interaction cycle length during multitask performance, one should not discard outliers in the data before verifying they their timing is uncorrelated to the steps of the task. Otherwise one might miss that or those steps which need redesign, in an otherwise sound interaction process.

Third, there will be situations where the driving task itself is so complex that engaging in any further tasks will be detrimental to driving performance. As this presents a form of upper boundary for task complexity, it follows that if a high quality assessment of the demands of the driving task can be made, one could in principle let drivers perform any non-driving related task which does not add to total task complexity in such a way that the boundary is crossed. Choosing when and where to let drivers perform non-driving related tasks based on primary task demand is often referred to as workload management. Initial steps have already been taken in this domain. For example, Volvo Cars have developed the Intelligent Driver Information System (IDIS), which delays information from the car's onboard systems or re-routes incoming calls to voice mail when on entrance ramps to freeways, etc. However, more can probably be done in this area, given the decreasing cost of sensors and computing power.

Fourth, most tasks listed in the NHTSA crash analysis and the NDS studies as distractions (e.g. eating, drinking, smoking, checking one's hair in the rearview mirror, engaging in conversations with passengers, reaching for items on adjacent seat, etc) are difficult influence through vehicle design. Moreover, inasmuch as some non-driving task engagement is driven by extra motives, it is difficult to conceive of a remedy based on vehicle design. One must therefore continue to expect that situations where driver performance is degraded due to non-driving related task engagement will continue to occur, even if the design of all in-vehicle system interactions should be perfected.

To mitigate the possible negative outcomes of these situations, a different strategy is required. Fortunately, one such strategy is already in place in form of the advanced driver assistance systems currently being developed by vehicle manufacturers, such as Forward Collision Warning and Lane Departure Warning. Basically, one way of describing what these systems do is to say that they mitigate effects of distraction. In other words, they are thought to be the most effective in situations where the driver unwittingly compromises his/her preferred safety margin, i.e. when the reassessment of the safety zone boundary is late or inadequate, and where the system can alert the driver to this problem.

While many of these systems are already being deployed, given the framework description above it follows that they most likely can be further refined by an onboard assessment of the driver's task state. If one knows when the driver is engaging in a non-driving related tasks (e.g. through head-/eye tracking, or similar), the driver assistance systems could be proactively tuned to this task state by for example temporarily increasing their sensitivity and/or giving the warning slightly earlier, should the need arise. In this way, it is possible to compensate for possible driver response delays due to the time needed for reassessment once the driver gets back in the loop   .

CONCLUSIONS

In this paper, a conceptual framework which uses the dimensions of arousal and adaptation and task complexity to characterize the relationship between performance on driving and non-driving related tasks, is outlined. An analysis of recent

studies on the prevalence of non-driving related activities in naturalistic driving studies and crash databases suggests that distraction cannot be understood as a linear relationship between secondary task involvement and crash risk. Instead, primary task demand, secondary task complexity, the level of arousal in the driver and any warning/intervention capabilities of the vehicle all need to be integrated and accounted for in order to accurately assess the extent to which secondary task involvement may degrade primary task performance. Based on this framework, several implications for the future design and availability of in-vehicle tasks are outlined, along with a discussion of which complementary steps may be necessary to fully mitigate the negative consequences of doing non-driving related tasks.

While the proposed framework may be overly complex for some situations (e.g., taking active safety systems into account will not be relevant for non-equipped vehicles), it is nonetheless believed that discussions and actions related to driver distraction will benefit from a more integrated, multidimensional framework for analyzing and understanding the difficulties distraction poses.

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