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Review article

Adolescence, Attention Allocation, and Driving Safety

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A B S T R A C T

Motor vehicle crashes are the leading source of morbidity and mortality in adolescents in the United States and the developed world. Inadequate allocation of attention to the driving task and to driving hazards are important sources of adolescent crashes. We review major explanations for these attention failures with particular focus on the roles that brain immaturity and lack of driving experience play in causing attention problems. The review suggests that the potential for overcoming inexperience and immaturity with training to improve attention to both the driving task and hazards is substantial. Nevertheless, there are large individual differences in both attentional abilities and risky driving tendencies that pose challenges to novice driver policies. Research that can provide evidence-based direction for such policies is urgently needed.

IMPLICATIONS AND CONTRIBUTION

Large individual differences in attentional capabilities as well as risky driving tendencies characterize the novice adolescent driver. However, the research reviewed suggests that significant opportunities exist to train the skills needed to become a safe driver and that continued research to inform safe driving policy should be a high priority.

Motor vehicle crashes are the leading source of mortality and morbidity in adolescents in the United States and most developed countries [1], and along with older drivers (ages 75 years +), adolescents (under age 20 years) have the highest rates of crashes per mile driven [2]. Driver inattention is a major source of crashes for both adults [3] and adolescents [4,5], with developmental factors playing a role for both older and younger drivers. For older drivers, the risk is a loss of cognitive and motor skills that can impair the ability to recognize and respond to road hazards and conditions [6,7]. For adolescent drivers, the risk is incomplete maturation of cognitive and motor skills, including working memory [8], visual-spatial attention [9], and speed of processing [10]. However, adolescents are also novice drivers, and so it is important to separate the effects of inexperience from developmental factors, in particular whether adolescents lack the *ability* to attend to driving tasks and road hazards due to immaturity in brain development [11,12], or are more susceptible to errors of misallocated attention due to *inexperience*. The

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former explanation would suggest delaying full licensure for adolescents until they have the requisite maturity to drive safely; while the latter would suggest more modest policies that consider both brain maturation and experience as important influences on adolescent driving ability.

There is reason for optimism regarding the role of experience. Efforts to enact three-stage graduated driver licensing (GDL) provisions have succeeded in reducing by nearly half the recent number of fatalities in crashes with adolescents behind the wheel [13–15]. Recognizing the key roles of maturity and experience on crash reduction, GDL's benefits were determined to result from restricting new young drivers' exposure to more challenging driving conditions. These restrictions are justified based on the continued reductions in crash rates that occur over at least the first 2 years of fully licensed driving, even in adults [16,17]. Nevertheless, a primary effect of GDL is likely attributable to brain immaturity, in that the first two stages of GDL (learner and provisional licenses) restrict the youngest drivers with the greatest crash risk (ages 16 years and younger) from driving under either unsupervised or high-risk conditions (e.g., night-time driving). More recent provisions address growing recognition of the role of inattention on crash causation by limiting peer passenger carriage and cell phone use. Requirements for adult-supervised practice driving during the learning period also increase the chances that novice adolescent drivers will gain experience before driving independently, and some evidence suggests that this may further reduce the risk for young drivers, especially when the period lasts for 12 months [18].

In this paper, we consider the role that both maturation and experience play in the allocation of attention to driving tasks. Some of the most prevalent crash configurations in adolescents, rear-end collisions, running off the road as a result of failing to negotiate a curve, and left turns at intersections [19], all have the potential to involve errors of attention [20,21]. Therefore, in this paper, we provide a foundation for future interventions and research regarding failures of attention among adolescent drivers. We first provide a model for categorizing various forms of inattention that can affect driver safety in novices. We then consider how both brain maturation and driving experience might affect those forms of inattention. We end with potential approaches to training and the need for future research that can enhance attentional skills in novice adolescent drivers. Although we focus primarily on studies of adolescents, we include research with adults when it is relevant to determining the effects of maturation versus driving experience.

Distinguishing different categories of inattention

The most widely accepted definition of driver inattention from Regan et al. [22], "insufficient, or no attention to activities critical for safe driving" (p. 1,775), broadly implies that the driver fails to allocate sufficient attention to the driving task in comparison with tasks that compete for attention. For the purposes of this review (see Figure 1), we further divide these activities into those that involve (1) failure to allocate attention to the road due to various forms of distraction or inability to maintain attention to the driving task (task inattention); and (2) failure to attend and respond to hazards even if one pays attention to the driving task (hazard inattention). We treat failures of attention to hazards as the proximate cause of crashes, and failures to attend to the driving task as one potential source of hazard inattention.

The model treats distraction as a relatively *transient* source of task inattention, or "a diversion of attention away from activities for safe driving…," as for example, attending to vehicle controls rather than the road [23]. For novice adolescent drivers, it is also important to consider potential *stable* sources of task inattention that stem from immature brain development or from chronic conditions, such as attention deficit/hyperactivity disorder (ADHD), the most common neurodevelopmental disorder in children and adolescents [24].

Figure 1 details various transient conditions that result in task inattention, some of which are longer in duration (e.g., physical inability to attend, such as drowsiness or alcohol intoxication) compared with more momentary distractions (e.g., dialing a cell phone, or attending to interesting people or scenes on the road). Also included in this category is mind wandering, when drivers monitor the road but focus their thoughts elsewhere [25].

Studies that examine brain activity while subjects engage in simulated driving tasks shed light on why even minor lapses in task attention can interfere with driving capability and reduce the ability to recognize hazards. These studies use functional magnetic resonance imaging to observe brain activity and have found that engaging in a cognitive task such as speaking on a phone while driving reduces activation in posterior visual regions and increases activation in frontal regions [26,27]. This can impede attentional resources directed to the visual field even though subjects outwardly maintain attention to the driving task. For example, a study using a driving simulator found that talking on the phone while driving reduced attention and response to a vehicle braking in front of the driver [28]. Mind wandering while driving can also divert attention from the visual field [25], suggesting that one does not need an explicit

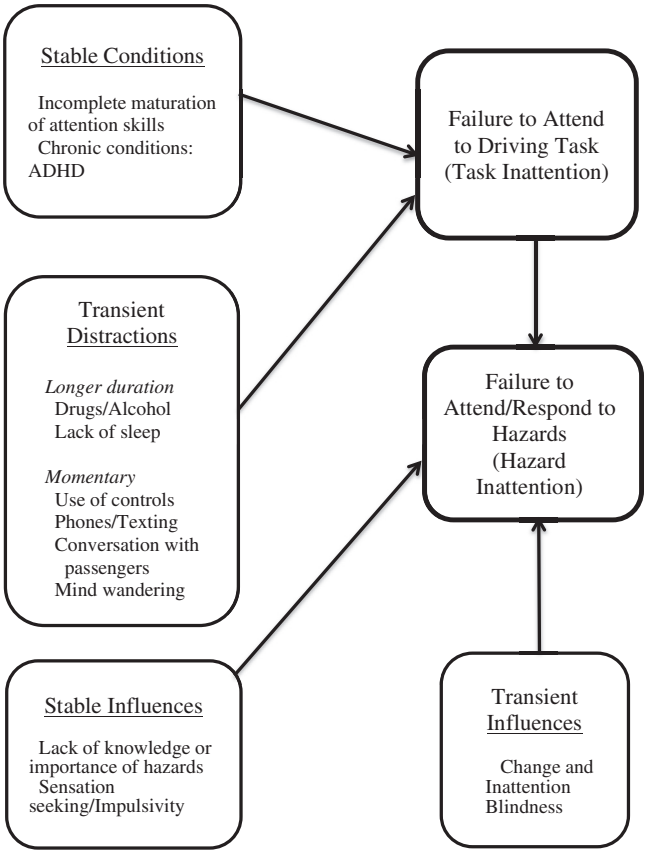

Figure 1. Model of sources of attention failures in novice drivers.