A new approach for assessing and training drivers’ speed management

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\textbf{A B S T R A C T}

Motor vehicle crashes are the leading cause of death and injury for teens and speeding is a major contributor, particularly driving too fast for conditions (CDC, 2015, 2013; NHTSA, 2012; Lam, 2003; McKnight & McKnight, 2003). Speed management is a type of tacit knowledge learned through experience that combines speed perception with decisions about safety. Effective training and assessment of speed management requires a safe method for accumulating practice that includes realistic perceptual cues. This study investigated whether speed can be manipulated in an online environment using special effects technology without distorting speed perception. A forced-choice experiment revealed that drivers’ perception of speed was not influenced by the special effects technology, indicating that critical perceptual information was not altered by the speed manipulation of the videos. The experiment also looked at the role of experience in detecting speed differences and found that experienced drivers were able to make judgments about speed more quickly than inexperienced drivers. Implications of these findings for training and assessment are discussed.

\section{Introduction}

Motor vehicle crashes are the leading cause of death and injury for teens accounting annually for nearly 3000 deaths, 100 times as many injuries, and over 14 billion dollars in associated costs in the U.S. (Insurance Institute for Highway Safety [IIHS], 2016; CDC, 2015, 2013). Speeding contributes to over 30% of teen driving crashes, as compared to 19% of crashes among adult drivers (NHTSA, 2012). Speeding includes driving too fast for conditions as well as exceeding the speed limit. Driving too fast for conditions includes failure to slow down to compensate for reduced visibility (e.g., rain) or vehicle handling (e.g., ice) as well as driving faster than other vehicles on the road (Aarts and Van Schagen, 2006).

Among teens, driving too fast for conditions is the primary cause of speed-related accidents, rather than intentionally risky driving (Lam, 2003; McKnight and McKnight, 2003). Curry et al. (2011) analyzed crashes involving 15–18 year old drivers from the National Motor Vehicle Crash Causation Survey (NMVCCS), a nationally representative sample of serious crashes. Driving too fast for conditions was the critical error leading to over 20% of crashes among teen drivers.

\subsection{1.1. Speed perception}

Human speed perception is a basic perceptual process, relying primarily on visual cues outside of the vehicle to estimate speed (Recarte and Nunes, 1996). Speed perception is highly sensitive to the amount of visual contrast in a scene, with reduced contrast leading to an underestimation of speed. Indeed, environmental conditions that obscure visual cues, such as darkness and fog, alter drivers’ perception of speed (Recarte and Nunes, 1996; Chatziastoros and Pretto, 2006; Reinhardt-Rutland, 1992). While inexperienced drivers drive slower on average, they do not proportionally decrease their speed to account for poor visibility, leading to a higher rate of collision from this group (Mueller and Trick, 2012).

Speed perception is also influenced by the relative speed of road, vehicle and peripheral objects. When asked to estimate the speed at which a vehicle is traveling participants underestimated high speeds and overestimated low speeds (Hills, 1980; Recarte and Nunes, 1996). More experienced drivers are better able to use speed and distance information to estimate time to collision (Cavallo and Laurent, 1988). Chatziastoros and Pretto (2006) found that the optic flow coming from the road in front of the car was critical in estimating the speed at which a vehicle was traveling. When the speed of the road in front of the traveling car was altered in a driving simulator, drivers adjusted to the speed of the road in front despite the presence of peripheral cues (e.g., traffic signs) traveling at a slower speed. Drivers also experience closing speed adaptation when driving on a straight open road for several minutes before approaching a vehicle, causing drivers to underestimate how quickly they are approaching a vehicle ahead on the roadway (Gray and Regan, 2005).
Visual characteristics of the roadway have an impact on driver’
decisions about what speed to drive, with drivers choosing slower
speeds on narrower roads (Charlton and Starkey, 2016), hilly and curvy
roads, when lane boundaries are difficult to see (Edquist et al., 2009)
and at night (Kockelman and Ma, 2007). Experienced drivers are also
better able to select appropriate speeds for conditions that require re-
duced speeds, such as slowing for objects on the side of the road and on
congested freeways (Kockelman and Ma, 2007), when there is a high
likelihood of vehicles entering the roadway (Edquist et al., 2009), and
when there are complex visual scenes to process. Inexperienced drivers
are less able to compensate for complex visual stimuli (Borowsky et al.,
2010) and are more likely to fixate on actual hazards (such as a pe-
destrian) and underestimate the danger of potential hazards (such as
low road visibility or closely following the car in front of them) which
leads young drivers to underestimate the danger of decreased visibility,
such as fog or darkness.

1.2. Social influences and driver characteristics

Social influences impact drivers’ choice of driving speed. Drivers
who report that both family and friends approve of speeding are more
likely to exceed posted speed limits than drivers who believe their
friends and families do not approve (Fleiter et al., 2006). Social influ-
ence interacts with driver characteristics such that young male drivers
who believe their friends speed are more likely to speed (Moller and
Haustein, 2014).

Drivers who experienced an incident that made them angry were
more likely to speed in a driving simulator, even miles after the incident
(Roidl et al., 2014). Drivers are also more likely to drive too fast for
conditions under time pressure and the impact of time pressure may be
explained by both the driver’s emotional state and by a cognitive bias
that leads drivers to underestimate their speed when under time pres-
sure (Coegnet et al., 2013). Experienced drivers are more likely to
adopt strategies to mitigate the tendency to speed under time pressure
than are novice drivers (LaVoie et al., 2008).

Driver characteristics are consistently associated with speed choice,
with males tending to drive somewhat faster than females (Hassan
et al., 2017; Anastasopolous and Mannering, 2016), drivers under 40
years of age driving faster than older drivers (Anastasopolous and
Mannering, 2016), and driver’s with a high income driving faster than
those with low or middle incomes (Kweon and Kockelman, 2006;
Hassan et al., 2017; Anastasopolous and Mannering, 2016).

1.3. Speed and tacit knowledge

Foss et al. (2011) determined that driving too fast for conditions
declines during the first 24 months of driving, closely following a power
curve and declining more quickly than overall crash rates. This in-
dicates that learning, rather than intentional risk-taking, aggressive
driving or overconfidence, is the cause of improvement.

The Safe Speed Knowledge Test measures drivers’ tacit knowledge
(knowledge gained through experience) about appropriate speeds in a
variety of contexts (Legree et al., 2003). These include environmental
conditions such as bad weather or road conditions known to increase
crash risk as well as personal conditions such as emotional states (e.g.,
anger, anxiety) or fatigue, factors that are prevalent and associated with
increased risks of traffic accidents (Alonso et al., 2017; Uthe et al.,
2017). Novice drivers experience a greater detriment from these factors
than more experienced drivers (Paxion et al., 2014). The Safe Speed
Knowledge Test successfully distinguished between drivers with a safe
driving history and those with a history of car crashes, establishing that
knowledge of appropriate speed is associated with reduced crashes.
Thus, training which improves speed management has significant po-
tential to reduce crashes among teen drivers.

Few options exist for providing novice drivers with opportunities to
acquire tacit knowledge of safe speeds. Digital video editing and special
effects techniques, such as those used in television and movies, may be
used to manipulate videos of vehicles driving so that vehicles appear to
moving at different speeds. Advances in web browsers have increased
the amount of interaction users have with videos embedded in web
sites. Recent changes include the ability to speed up or slow down a
video. Changing the speed of a video of a vehicle taken from a driver’s
point of view makes the vehicle appear to moving at faster or slower
speeds.

This paper describes an experiment conducted to determine whe-
ther digital video editing and special effects techniques can be used to
manipulate vehicle speed in digital videos designed to be shown in a
web-based environment while maintaining perceptual realism. This was
tested using a forced-choice perception experiment and a series of
driver’s point of view videos, either edited with VFX to increase and
decrease speed, or left unedited. A secondary question was whether
experienced drivers would be more sensitive to differences in speed
than inexperienced drivers. A third question was whether there would
be an interaction between VFX editing and driving experience, such
that experienced drivers would be more likely to detect differences in
vehicle speeds in the edited videos.

2. Method

2.1. Participants

Participants were recruited from the community and through email
blasts sent to parents of adolescents who received care at a large pe-
diatric care network. Sixteen teens (10 females) and 16 adults (9 fe-
males) participated in the experiment. Participants met the following
requirements: teens were between 14 and 17 years old and had less
than one year of driving experience, and adults were between 28 and 55
years old and had at least 10 years of driving experience with no
moving violations or at-fault accidents in the past 5 years.

Consent to participate was obtained in-person: teen participants
provided written assent and adult participants provided written con-
sent. Upon consenting, eligibility of participation was verified. The
recruitment, enrollment, and screening processes were approved by the
large pediatric care network’s Institutional Review Board.

2.2. Stimuli. Baseline and manipulated videos

Digital video editing and special effects techniques were used to
manipulate vehicle speed in a series of digital videos. Baseline videos
were filmed from a driver’s point of view through the front windshield
of a vehicle on a closed course track at a steady speed that captured the
forward roadway and the sides of the road. Videos were created using a
camera mounted inside a vehicle. Videos were filmed at vehicle speeds
of 15 mph, 20 mph, 25 mph, 30 mph, 35 mph, 40 mph and 45 mph. These
original videos were then manipulated to create a series of videos
where the vehicle appears to be moving at different speeds. Videos were
cleaned of minor artifacts (e.g., windshield dust) and trimmed of initial
acceleration and final deceleration, prior to applying any speed ma-
nipulation effect. No adjustments were made for exposure, color, or
contrast to any of the footage in order to avoid confounding the speed
manipulation. Manipulated videos were created from each baseline
video by adjusting the speed in 5mph increments. For example, the
baseline 20 mph video was manipulated to create several new videos in
which the vehicle appears to travel at 15 mph, 25 mph, 30 mph, 35 mph,
40 mph and 45 mph. Manipulated videos were created by ap-
plying a time adjustment effect to the baseline video that best described
how each pixel changed from frame to frame in order to create the most
realistic speed adjustment (as opposed to just removing or blending
whole frames together). In order to accomplish this, a commercial off-
the-shelf video effects system was used to adjust the pixel motion (i.e.,
parts of the image that are in motion). The manipulated videos appear
to be identical to the baseline videos except that the vehicle is moving
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