Overview of Behavioral Adaptation Research and ADAS

Reaching Zero Crashes: A Dialogue on the Role of Advanced Driver Assistance Systems

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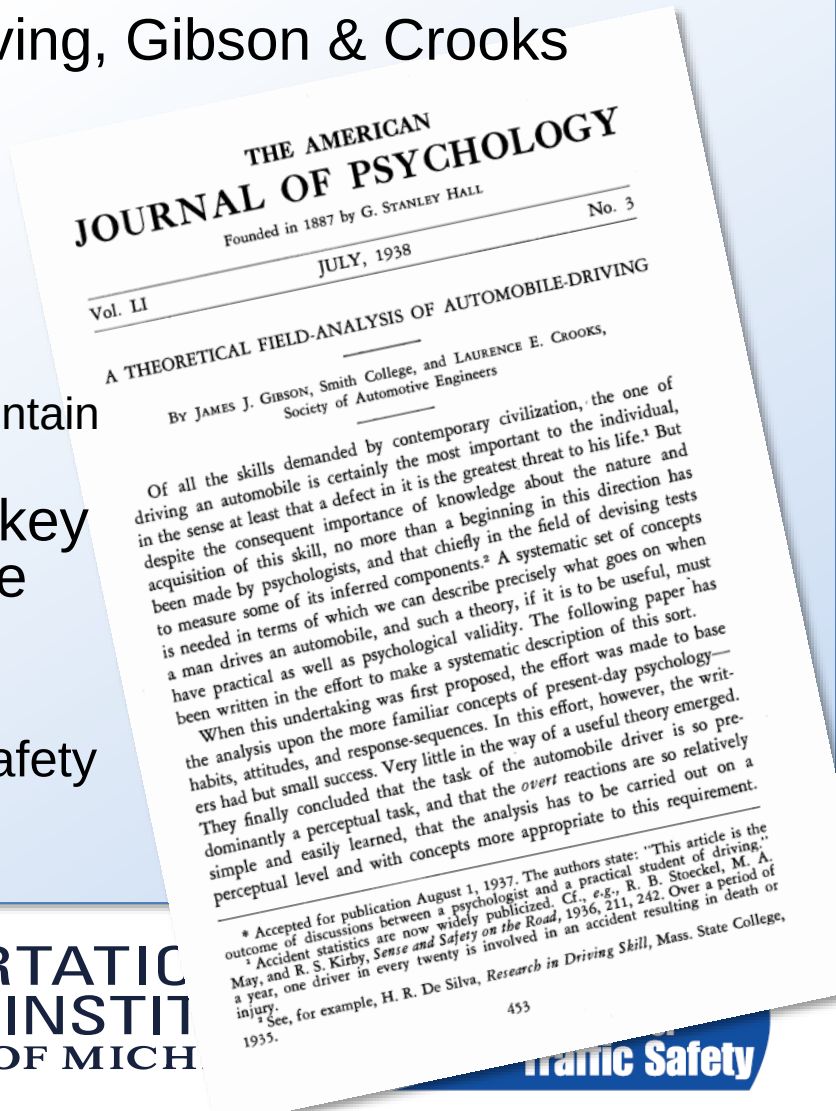
Overview

- What is behavioral adaptation?
  - Early ideas
  - OECD definition
  - Early examples
- Behavioral adaptation models in historic context
  - “Zero-risk” theory
  - Risk homeostasis theory
  - Looking beyond motivational theories
- ADAS technologies and new models of behavioral adaptation
  - Fragmentation of the driving task into part-task driver support
  - Part-task automation and driver engagement
  - Driver personality, trust, and understanding ADAS technology

Historical perspective: Behavioral Adaptation (BA) has been a concern since 1938

- In an early study of automobile driving, Gibson & Crooks (1938) noted that:
  - "…more efficient brakes will not in themselves make driving any safer." Because, they argued:
    - The driver will learn the minimum stopping zone
    - And the driver will adjust braking to maintain the same safety margin as before.
- Behavioral Adaptation has been a key concern for both active and passive safety
  - It is difficult to predict
  - It threatens to undermine expected safety benefits



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A THEORETICAL FIELD-ANALYSIS OF AUTOMOBILE-DRIVING

By James J. Gibson, Smith College, and Laurence E. Crooks, Society of Automotive Engineers

Of all the skills demanded by contemporary civilization, the one of driving an automobile is certainly the most important to the individual, in the sense at least that a defect in it is the greatest threat to his life.[1] But despite the consequent importance of knowledge about the nature and acquisition of this skill, no more than a beginning in this direction has been made by psychologists, and that chiefly in the field of devising tests to measure some of its inferred components.[2] A systematic set of concepts is needed in terms of which we can describe precisely what goes on when a man drives an automobile, and such a theory, if it is to be useful, must have practical as well as psychological validity. The following paper has been written in the effort to make a systematic description of this sort.

When this undertaking was first proposed, the effort was made to base the analysis upon the more familiar concepts of present-day psychology—habits, attitudes, and response-sequences. In this effort, however, the writers had but small success. Very little in the way of a useful theory emerged. They finally concluded that the task of the automobile driver is so predominantly a perceptual task, and that the *overt* reactions are so relatively simple and easily learned, that the analysis has to be carried out on a perceptual level and with concepts more appropriate to this requirement.

* Accepted for publication August 1, 1937. The authors state: "This article is the outcome of discussions between a psychologist and a practical student of driving."

[1] Accident statistics are now widely publicized. Cf., *e.g.*, R. B. Stoeckel, M. A. May, and R. S. Kirby, *Sense and Safety on the Road*, 1936, 211, 242. Over a period of a year, one driver in every twenty is involved in an accident resulting in death or injury.

[2] See, for example, H. R. De Silva, *Research in Driving Skill*, Mass. State College, 1935.

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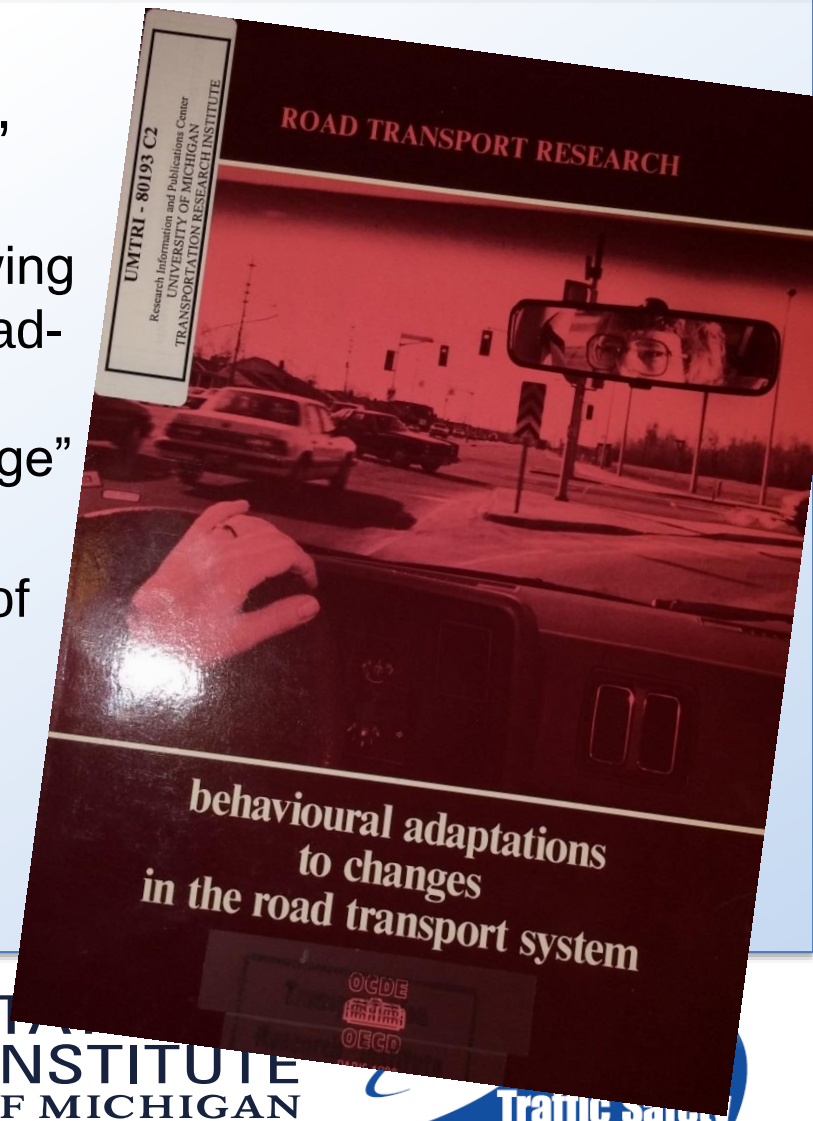
Organization for Economic Co-operation and Development (1990) Report

- Examined behavioral adaptation, defining adaptation as:
  - "…behaviors which may occur following the introduction of changes in the road-vehicle-user system which were not intended by the initiators of the change"
  - The OECD examined adaptation effects on overall safety in a variety of contexts



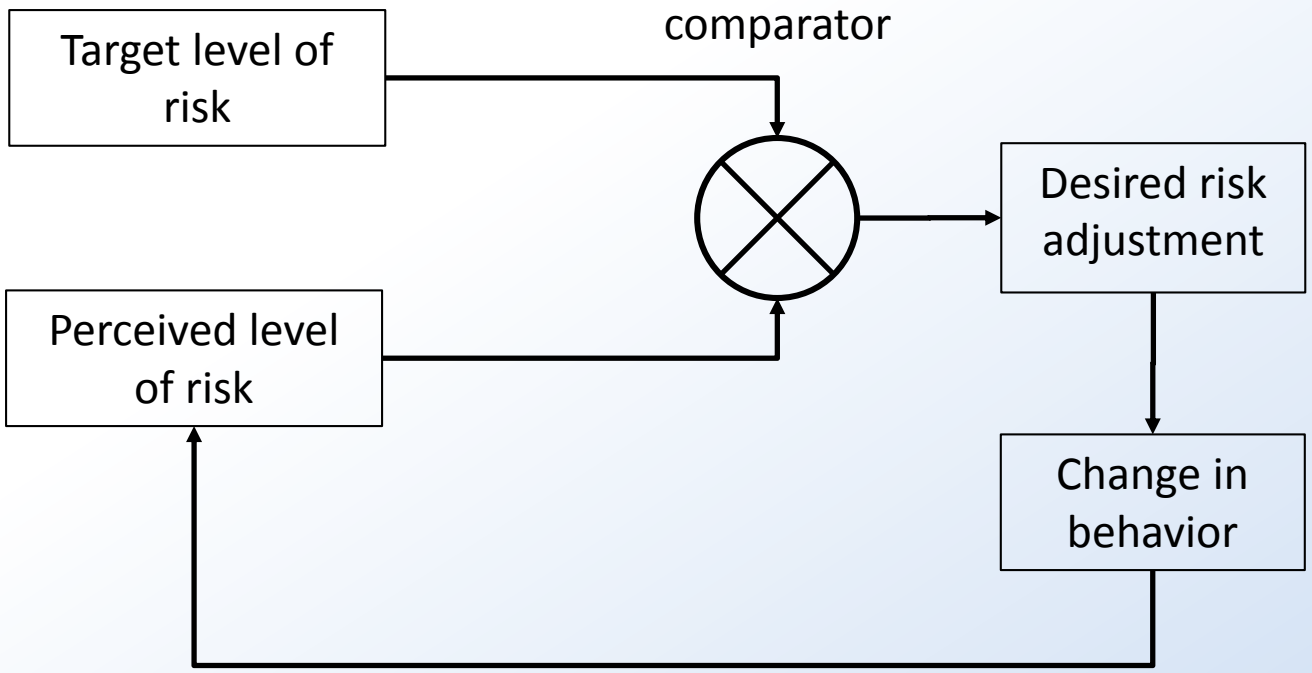
Most initial improvements were related to performance and occupant protection

- It was argued that behavioral adaptation occurred in response to drivers feeling safer—drivers might offset this perception of reduced risk, by taking more risks in their driving:
  - Increased aggressive maneuvering
    - Speeding
    - Increased lane changing
    - Hard braking
  - Close following distance
  - Small gap acceptance

Initial theories of behavioral adaptation

- Zero-risk theory (Näätänen & Summala,1974)
  - Drivers monitor subjective risk continuously
    - Risky action is allowed when no risk is detected
    - Risky action is inhibited when subjective risk exceeds a critical point
- Risk Homeostasis (Wilde, 1982)
  - Drivers regulate risk by evaluating the utility of risky behavior and its cost against the utility of safe behavior and its cost.
    - The theory suggests that any measure to improve driver safety is offset by a behavioral change—no net improvement in safety
- Risk Allostasis Theory (Fuller, 2005)
  - Drivers balance their perceived capability to handle a task with perceived difficulty of the task

Motivational theories



ADAS has changed the view of behavioral adaptation

- ADAS technologies do more than enhance vehicle performance—they now support and share specific parts of the driver's task:
  - Control functions:
    - ACC, LKA
  - Lookout functions:
    - Forward collision, Lane departure, Rear cross traffic, Side object
  - Extend driver sensory capability:
    - Night vision pedestrian/animal detection
  - Automatic intervention:
    - CIB, ESC, ABS

New models of BA look for specific behavioral effects

- Adaptation is influenced by the driver's:
  - ***Mental Model*** of how the ADAS functions
  - Personality factors
  - Trust/belief
- Effects of BA play out at different performance levels of the driving task:
  - Strategic
  - Tactical
  - Operational

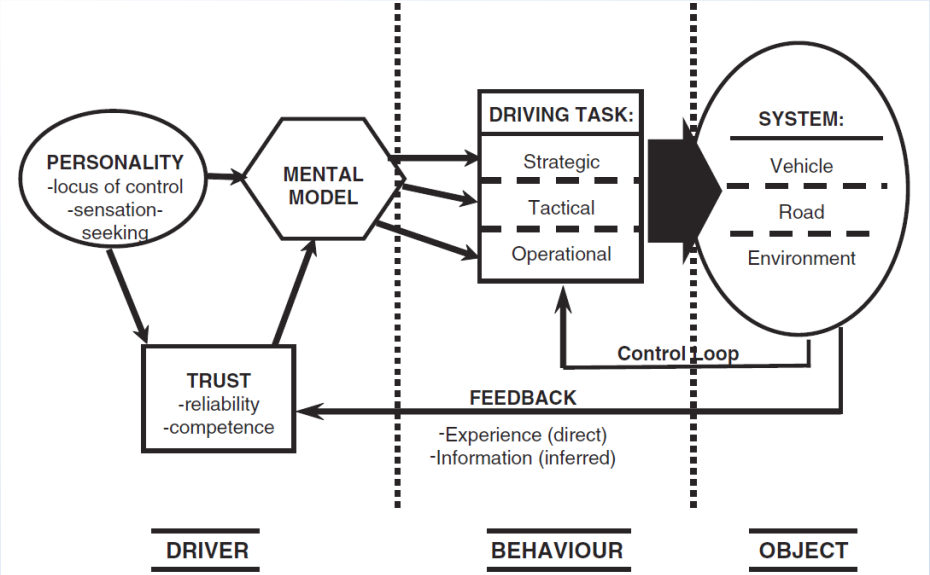


Fig. 1. Qualitative model of BA (from Rudin-Brown & Noy, 2002).

What does BA look like?

- Change in **control behavior**
  - Increased response time to hazards or system failure
  - Shorter following distance
  - Decreased monitoring forward scene
- Change in **tactical behavior**
  - Decreased overtaking maneuvers
  - Cruise speed settings increased when a lead vehicle is present
  - Passing maneuvers begin at greater distance from forward vehicle
- Change in **strategic behavior**
  - Increased engagement in non-driving secondary tasks
  - Loss in situation awareness
  - Preferences for roadways that better support ADAS

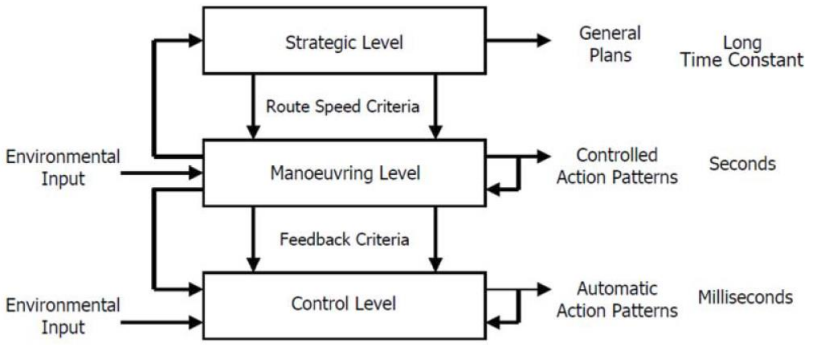


Figure 1. A hierarchical model of the task of driving (from Michon, 1985).

State of research on BA

- Last 20 years:
  - Mostly simulator-based studies
  - Mostly lateral, longitudinal, or “highly-automated” control studies
  - Mostly limited exposure durations—20-45 minutes
  - Concern focused on **over-trust** of system; loss of situation awareness
- Recent trends:
  - Interest in driver’s trust and **mental model** of ADAS
  - More longitudinal studies of how trust and understanding develop
  - More on-road/field studies over longer periods of time
  - Increased interest in longer-term behavior adaptation

Some conclusions about Behavioral Adaptation and ADAS

- Behavioral adaptation to ADAS is highly variable and depends on:
  - How obvious is the ADAS intervention?
  - How much exposure does the driver receive?
  - What does the driver understand about ADAS capabilities (mental model)?
  - If ADAS limits are rarely encountered, drivers will be likely to forget them and be unprepared to intervene
  - Adaptation effects will likely be specific to the ADAS

Thank you

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