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Calibration of skill and judgment in driving: Development of a conceptual framework and the implications for road safety

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A B S T R A C T

Humans often make inflated or erroneous estimates of their own ability or performance. Such errors in calibration can be due to incomplete processing, neglect of available information or due to improper weighing or integration of the information and can impact our decision-making, risk tolerance, and behaviors. In the driving context, these outcomes can have important implications for safety. The current paper discusses the notion of calibration in the context of self-appraisals and self-competence as well as in models of self-regulation in driving. We further develop a conceptual framework for calibration in the driving context borrowing from earlier models of momentary demand regulation, information processing, and lens models for information selection and utilization. Finally, using the model we describe the implications for calibration (or, more specifically, errors in calibration) for our understanding of driver distraction, in-vehicle automation and autonomous vehicles, and the training of novice and inexperienced drivers.

1. Introduction

As hungry processors of information, we humans selectively attend to environmental cues and render judgments concerning the state of the world around us. At the same time and with some degree of introspection, we carry out self-appraisals, evaluating how skillful or capable we are in different contexts. Both the manner in which we perceive the world, as well as our perceptions of our own effectiveness as agents in the world, can have a tremendous bearing on the decisions we make, the behaviors we engage in, and the risks we entertain. While these perceptions of world and self often lead to reasonable decisions and behaviors as well as tolerable levels of risk, the more profound interest emerges in situations where the subjective perception of the world or of self deviates from objective reality, with potentially negative consequences. For example, a driver, thinking that current driving conditions are easy, sends a text message—having failed to notice a nearby hazard; the driver with a highly reliable automated system comes to distrust and disuse it for what the driver wrongly considers to be too many false alarms; the novice driver, overconfident in their driving skills and abilities, travels at a high speed on a slippery surface.

Gaps between perception and reality can be related to the notion of calibration, which itself can be broadly defined as the determination of the accuracy of an instrument by measurement of its variation from a standard. Despite having a strong foundation in the physical sciences, calibration is not unique to this context. The concept of calibration also has prominence in the social and psychological sciences—often in situations where one's ability to make sufficiently accurate judgments to guide decision-making and behavior is paramount. Indeed, calibration has been widely discussed in a variety of domains, including weather forecasting, education, scholastic aptitude, medicine, work and management, eye witness testimony, as well as driving. Within these fields, some researchers have focused on whether or not individuals' perceptions are in (or out of) alignment with an objective standard while others have focused on managing task demands and user capabilities as a means of bringing two measurements or estimates into alignment (e.g., Kuiken and Twisk, 2001; Fuller, 2005; Mitsopoulos-Rubens, 2010).

In the current paper, we discuss calibration as it relates to general self-appraisals and evaluations of one's competence in making perceptual judgments (the state of calibration) as well as to models of

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self-regulation in driving (which are concerned with the process of bringing subjective and objective measures into alignment). We further propose a framework for calibration in the driving context, building and elaborating upon some earlier models of momentary demand regulation (e.g., Fuller, 2005; Mitsopoulos-Rubens, 2010), models of information processing (e.g., Wickens and Hollands, 2000), and lens models for information selection and utilization (e.g., Brunswik, 1955; Hammond, 1955). We illustrate how different components in the model can account for some of the errors and deficiencies in calibration observed in the literature and, in so doing, overcome possible shortcomings in some previous models of calibration in driving. Finally, we describe the practical implications of calibration for road safety through three examples: our understanding of driver distraction, in-vehicle automation and autonomous vehicles, and the training of inexperienced drivers. It is hoped that the framework will provide guidance to research efforts concerning the role of calibration in the study of road safety; help account for discrepancies between perception, performance and skill; and lead to approaches aimed at mitigating potentially adverse effects of miscalibration.

2. Calibration failures

Errors in calibration have important implications for safety and performance and can be due to deficiencies in the processing of available information, errors in evaluated self-competence and/or comparison errors. The failure to process, or appropriately weigh, highly critical information can result in a slanted, narrow, or erroneous awareness of the situation (e.g., Griffin and Tversky, 1992). Similarly, an unrealistic appraisal of our own skills and abilities—while promoting good feelings of self-worth and esteem—can also place us in situations that we are ill-equipped to deal with.

Evidence from various domains suggests that individuals' subjective impressions or evaluations are not well-calibrated to more objective measures. People generally tend to view themselves in favorable or optimistic terms—regardless of the degree of truth in the assertion (e.g., Brown, 1986; DeJoy, 1989; Dunning et al., 2004). This tendency has been couched in many different terms, such as optimism bias, self-enhancement bias, illusory superiority, among many others (e.g., Sharot, 2011; Hoorens, 1993). Studies of self-efficacy, self-appraisal, self-confidence, and other forms of self-evaluation are widespread in the social and psychological scientific literature. Indeed, there is such a plethora of work in this area that it can even support meta-syntheses of dozens of meta-analyses (e.g., Zell and Krizan, 2014). Findings of enhanced self-appraisals are evident in almost every discipline, including education and learning (e.g., Bol and Hacker, 2012), ethics (e.g., Baumhart, 1968), health and medicine (e.g., Larwood, 1978; Weinstein, 1980; Dunning et al., 2004) and workplace and managerial skills (e.g., Larwood and Whittaker, 1977). This is also the case for self-appraisals with respect to driving skills and abilities. Many studies have documented drivers' tendency to rate themselves more favorably than other drivers or to rate their skills as better than indicated by some objective standard (e.g., Svenson, 1981; McKenna et al., 1991; DeJoy, 1989; Brown and Groeger, 1988; Horswill et al., 2004).[1]

Errors in calibration have also been widely documented in decision-making and judgment paradigms, particularly where uncertainty is a critical element. Calibration, in this framework, is often characterized mathematically as the correspondence between one's confidence in a judgment (degree of certainty) and the accuracy of the judgment (e.g., Murphy, 1973; Lichtenstein and Fischhoff, 1977; Lichtenstein et al., 1982; Baranski and Petrusic, 1994, 1995; Soll, 1996).

Dunning et al. (2004) reviewed evidence for imprecise or flawed self-assessments, citing poor correlations between self-ratings of skill and actual performance as well as the tendency for people to overrate themselves (placing themselves as better than average)—outcomes echoed by many (e.g., Zell and Krizan, 2014; Mabe and West, 1982). These latter ratings are sometimes manifest as overestimates in their engagement in desirable behaviors or in their achievement of favorable outcomes, overly optimistic estimates of future productivity, and over-confidence in judgments. Dunning et al. (2004) further suggested that these errors in calibration can result from incomplete information, on the one hand, and neglect of relevant information, on the other (i.e., in the diligent processing and appropriate weighing of information). Errors can likewise result from incomplete or inadequate processing of available information (through heuristics or selection), biases or other top-down influences (e.g., Slovic et al., 1977; Kahneman and Tversky, 1972).

As hinted in Section 1, our own self-appraisals and evaluations can affect how we interact with the world. Yet many studies do not examine the roles of action or feedback in such evaluations (cf., Simons, 2013; Stone and Opel, 2000). The next section describes how the process of bringing different measures or estimates into alignment has been implemented in models of driving behavior. While "state" errors in calibration of self-evaluation and ability, such as those described above, are inherent to these models, the focus is on the process of appraisal and action regulation (i.e., self-regulation or momentary demand regulation; e.g., Kuiken and Twisk, 2001). Given the dynamic and self-paced nature of driving as well as the lack of a clear gold standard for driving safety/performance, one could argue that the regulatory process is more germane in the driving context than general appraisals of self and skill (although both are important).

2.1. Theories of demand regulation in driving

Several models of driver behavior treat calibration as a regulatory process in which the driver balances the momentary assessment of ability and the assessment of demand. For example, the task-capability interface model (Fuller, 2005) posits that drivers will adopt a preferred level of driving difficulty. Whenever task difficulty exceeds the preferred range, drivers will make behavioral adjustments to return difficulty to the desired range. Difficulty is a property that emerges from the interaction between driving demands and driver capacity (see similar models described by Davidse et al., 2010; de Craen, 2010; Mitsopoulos-Rubens, 2010). Driving demands are determined in part by speed, road, environment, and other driving properties. Driver capabilities (i.e., capacity) are determined by many factors including biological factors, knowledge, skills, and allocation of resources. The "fit" between driver demands and capabilities contributes to the perceived difficulty of the tasks.

Safe or successful performance is therefore contingent upon the ability of drivers to recognize the relationship between demands of the driving task and their own capabilities. When demands of the driving task exceed a driver's capabilities, the well-calibrated driver will recognize this difficulty and take measures to bring the two into alignment. For example, by reducing speed, a driver may ease the time pressure and challenges of vehicle control associated with a curvy stretch of road. Drivers that are not well-calibrated might fail to take protective countermeasures thereby placing themselves at risk (e.g., Deery, 1999; Spolander, 1983).

[1] We do note that, here and elsewhere, these studies often define or contrast between overconfidence, overestimates or over-placement in different ways. A fair and cogent treatment of these issues, however, is beyond the intended scope of the current effort.