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A Primer on the Human Readiness Level Scale (ANSI/HFES 400-2021)

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ABSTRACT

The Human Readiness Level (HRL) Scale is a simple 9-level scale for evaluating, tracking, and communicating the readiness of a technology for safe and effective human use. It is modeled after the well-established Technology Readiness Level (TRL) framework that is used throughout the government and industry to communicate the maturity of a technology and to support decision making about technology acquisition. Here we (1) introduce the ANSI/HFES 400-2021 Standard that defines the HRL scale and (2) provide concrete examples of evaluation activities to support the application of HRLs in the development of automated driving systems.

Keywords: Human readiness levels, Technology readiness levels, SAE levels of automation, Human systems integration, Autonomous vehicles, Standards

INTRODUCTION

The Human Readiness Level (HRL) scale is a nine-level scale designed to supplement the Technology Readiness Level (TRL) scale widely used throughout U.S. Department of Defense (DoD) (Government Accountability Office, 2020). While the TRLs assess the maturity of a technology before and after it is integrated into a developing system, the HRLs were developed to focus on the readiness of the system for use by human operators and maintainers (Handley & Savage-Knepshield, 2020).

The goal of the HRL scale is to indicate the state of integration within the system with respect to humans and technology. The evaluation of the HRL focuses on the system's readiness for human usability and incorporates the human element as part of the systems lifecycle development. HRLs have the potential to minimize the cost of design changes, through early identification of human issues, and reduce human error in fielded systems by tracking the mitigation of identified issues through subsequent HRL assessments (Salazar et al., 2021). The HRL scale shifts attention from lagging indicators of human readiness, such as human error in fielded systems, to leading indicators – namely, the evidence-based measures of system usability readiness derived through the application of the HRL scale (See, 2021).

The HRLs were first proposed as a measure to communicate on the readiness of a system for use by human operators and maintainers in 2010 (Acosta, 2010). Additional progress was made by a DoD Human Systems Integration (HSI) working group that refined the scale with more detailed definitions and descriptions (Phillips, 2015). In 2019, a new HRL working group consisting of a cross section of DoD, industry and academic experts served as the writing committee for an HRL standard; the Human Factors & Ergonomics Society (HFES)/American National Standards Institute (ANSI) 400-2021 "Human Readiness Level Scale in the System Development Process" was approved in 2021 (Handley, 2021). The standard defines the nine levels of a Human Readiness Level (HRL) scale and provide guidance for their application (HFES/ANSI, 2021). The nine HRLs are defined as follows:

- *HRL1:* Basic principles for human characteristics, performance, and behavior observed and reported
- *HRL2:* Human-centered concepts, applications, and guidelines defined
- *HRL3:* Human-centered requirements to support human performance and human-technology interactions established
- *HRL 4:* Modeling, part-task testing, and trade studies of human systems design concepts and applications completed
- *HRL 5:* Human-centered evaluation of prototypes in mission-relevant part-task simulations completed to inform design
- *HRL 6:* Human systems design fully matured and demonstrated in a relevant high-fidelity, simulated environment or actual environment
- *HRL 7:* Human systems design fully tested and verified in operational environment with system hardware and software and representative users
- *HRL 8:* Human systems design fully tested, verified, and approved in mission operations, using completed system hardware and software and representative users
- *HRL 9:* System successfully used in operations across the operational envelope with systematic monitoring of human-system performance

Human readiness levels (HRLs) were designed to mirror the TRL's and their familiar nine-level scale. However, rather than focusing solely on technology, HRLs consider the readiness of the technology or system to support the human (See et al., 2019). They provide a set of supporting questions at each level that describe the fundamental activities to ensure human considerations are appropriately addressed and an objective, structured approach for assessing a system's readiness for human use. The HRL scale addresses a need in both the DoD and industry for a metric to convey Human System Integration (HSI) maturity and related program risk (Schwartz & Dodson, 2021). HSI practitioners can utilize the HRL standard to demonstrate the importance of HSI investment, quantify the success of their efforts accurately and reliably, and gain leadership buy-in.

Handley and Savage-Knepshield (2020) examined the suitability of HRL use for an army acquisition program. They reviewed previous HSI assessments that tracked the program's progress across acquisition milestones and using the HRLs identified which issues persisted over time. Their analysis

mapped documented HSI issues to the HRL underlying questions. Results demonstrated that when issues were resolved during system development, the HRL increased, and when they remained unresolved, the HRL remained flat thereby providing evidence that HRLs could be used to convey the readiness of a system to interface with a human operator (Savage-Knepshield, Hernandez & Sines, 2021). The use of the assigned HRL rating readily communicates the readiness of a technology or system for human use to program and acquisition managers to support decisions regarding future program direction and allocation of funding (See, 2021).

APPLYING ANSI/HFES 400-2021 TO ADVANCED DRIVING SYSTEM (ADS) TECHNOLOGY

The ANSI/HFES 400-2021 standard (HFES/ANSI, 2021) includes an appendix with evaluation guidance that includes examples of representative evaluation activities, criteria for exiting one level and transitioning to the next, and descriptions of the type of supporting evidence that should be provided to indicate that these criteria have been met.

Below we outline representative evaluation activities at each HRL, using Honda's (2021) Traffic Jam Pilot (TJP) as an example. TJP is an SAE Level 3 feature that allows the system to fully take over the driving task in congested traffic. At SAE Level 3, also referred to as Conditional Driving Automation, an ADS is capable of performing all routine aspects of the driving task within a specific operational design domain (ODD), provided the fallback-ready driver is receptive to requests to intervene and able to respond in the event of an automation failure (SAE, 2021). For TJP, the ODD includes slow-speed driving in a single lane. The system monitors the environment and provides both lateral and longitudinal control under this narrow set of roadway conditions and speeds. When the system is active, the driver is not required to monitor the system and may use the infotainment system to engage in other tasks like watching movies or navigation. The system uses vibration in the seatbelt to alert the driver to regain control of the vehicle and colored lights illuminate the steering wheel to indicate which advanced driving feature is activated. Cameras monitor the driver at all times, and the system is able to make an emergency stop if the driver is non-responsive.

In Table 1, we present the exit criteria and a sample evaluation question, drawn from Appendix C of ANSI/HFES 400-2021. We've listed only one of the many recommended evaluation questions included in the standard appendix. At all HRLs, human system experts are responsible for specifying which of the recommended evaluation questions are relevant and whether those questions have been answered positively. The examples below are based on publicly available information about the TJP system. TJP technology pre-dates the ANSI/HFES 400-2021 standard, and the authors do not have specific knowledge about Honda's approach to assessing human readiness. However, the example does provide a representative use case for how HRLs could have been applied within the development process.

Table 1. HRL evaluation questions and examples for TJP system.

HRL 1: Basic Human Research
Exit Criterion: In order to exit HRL 1 and advance to the next level, human involvement relevant to the developing concept or proposed applications should be identified and characterized at a basic level. **Sample Evaluation Question C.1.1.1:** Have key human behaviors, capabilities, and limitations been identified? **Example:** HSL 1 requires initial consideration of both the activities that the driver will be allowed to engage in while TJP is engaged and the human performance characteristics that are relevant to capturing the driver's attention to re-engage in the driving task. TJP uses haptic feedback in the seatbelt to alert the driver of the need to resume the driving task. Documentation might include studies on the efficacy of various haptic warning types.
HRL 2: Human Centered Design Guidelines
Exit Criterion: In order to exit HRL 2 and advance to the next level, key human-centered design and training principles, standards, and guidance for human interaction with the technology or for human performance augmentation should be established. **Sample Evaluation Question C.2.1.2:** Have key human-centered design principles, standards, and guidance been established? **Example:** HSL 2 requires the identification of relevant design standards. As TJP uses haptic feedback in the seatbelt to capture driver attention and to initiate a driver takeover, this would include the identification of haptics-related ISO standards (e.g., ISO 9241-910, Ergonomics of human-system interaction — Part 910: Framework for tactile and haptic interaction and ISO 9241-920, Ergonomics of human-system interaction — Part 920: Guidance on tactile and haptic interactions.)
HRL 3: Human Centered Requirements
Exit Criterion: In order to exit HRL 3 and advance to the next level, required human-centered analyses are completed and human-centered requirements and KPPs are identified and flowed into high-level system requirements. **Sample Evaluation Question C.3.1.5:** Have situation awareness information flow and sharing requirements across teams of human or automated system components been identified? **Example:** The TJP feature is available only under a specific ODD when other Advanced Driver Assistance Systems (ADAS; e.g., Adaptive In-Lane Driving and active lane change) are engaged. When ADAS are engaged, the driver is responsible for monitoring. When Level 3 features are engaged, the system is responsible for all aspects of the driving task. Transitioning between ADAS and the more highly automated Level 3 driving features requires communication between the automated system components and the human user. During HRL3, the information sharing requirements regarding the driver's role, the automation mode, and the actions that the vehicle is taking (changing lanes) should be identified.

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Table 1. Continued.

HRL 4: Part-Task Testing
Exit Criterion: In order to exit HRL 4 and advance to the next level, human interactions and performance are evaluated and characterized, using analytical tools, modeling, and part-task testing with rapid prototypes and mockups. Task analyses and human-machine function allocations are updated. Human systems designs, HSI domain strategies, and human performance results must be deemed satisfactory by human systems experts. **Sample Evaluation Question C.4.1.12:** Have relevant human performance data been collected and evaluated to determine whether human performance metrics are successfully met, based on modeling and part-task testing? **Example:** HRL 4 evaluation activities may include laboratory-based simulator studies to assess the effectiveness of visual, auditory, and haptic alerts on takeover behavior on representative tasks and fallback condition.
HRL 5: Prototypes in Mission-Relevant Simulations
Exit Criterion: In order to exit HRL 5 and advance to the next level, human interactions and performance with developing system prototypes are evaluated and characterized in the context of more realistic mission-relevant part-task simulations with higher fidelity and users independent from the design team. Human performance results must be deemed satisfactory by human systems experts. **Sample Evaluation Question C.5.1.12:** Have relevant human performance data been collected and evaluated to determine whether human performance metrics are successfully met, based on prototype testing in mission-relevant part-task simulations? **Example:** HRL 5 evaluation activities may include the use of a fixed based simulator to assess takeover performance, fallback condition, situation awareness, and system usability during the transitions between ADAS and the more highly automated Level 3 driving features.
HRL 6: Human Systems Design Fully Matured
Exit Criterion: In order to exit HRL 6 and advance to the next level, human interactions and performance are evaluated and characterized in the context of high-fidelity simulated or actual environments with a functional and realistic prototype, representative users, and the full range of usage scenarios and tasks. Human performance results must be deemed satisfactory by human systems experts. **Sample Evaluation Question C.6.1.2:** Has the full range of user scenarios and tasks been tested in high-fidelity simulated or actual environments? **Example:** HRL 6 evaluation activities may include the use of a high-fidelity simulator or a test vehicle on a closed track to assess the effects of extended use of the infotainment system and other personal technologies on situation awareness and takeover performance.
HRL 7: Human Systems Design Fully Tested
Exit Criterion: In order to exit HRL 7 and advance to the next level, human interactions and performance are evaluated and characterized in an operational environment with the final development system, representative users, and the full

Continued.

Table 1. Continued.

range of usage scenarios and tasks. Human performance results must be deemed satisfactory by human systems experts. **Sample Evaluation Question C.7.1.11:** Have relevant human performance data been collected and evaluated to determine whether human performance metrics are successfully met, based on testing with the final development system in an operational environment? **Example:** HRL 7 evaluation activities may include data collection using the final developed system on a closed test track, with representative users and a range of scenarios.
HRL 8: Human Systems Design Verification and Approval
Exit Criterion: In order to exit HRL 8 and advance to the next level, human interactions and performance are evaluated and characterized with the production system in mission operations during the full range of usage scenarios and tasks completed by representative users. Human performance results must be deemed satisfactory by human systems experts. **Sample Question C.8.1.1:** Has the range of user scenarios and tasks been tested with the production system in mission operations? **Example:** Prior to commercial release, Honda's TJP-equipped Legend sedan was tested on over 1.3 million km of road (Honda, 2021). HRL 8 evaluation activities would require that this testing and evaluation include representative users and a full range of usage scenarios, including emergency and other non-normal events. During these tests, human performance data should be collected and documented, and any human performance issues should be resolved.
HRL 9: Operational Use and Monitoring
Exit Criterion: Like TRL 9, HRL 9 does not have a distinct or well-defined conclusion. A fielded system continues to be monitored, tested, and evaluated to ensure it supports the mission as intended. **Sample Evaluation Question C.9.1.5:** Is user training for operation of the fielded system being evaluated for required modifications? **Example:** In 2021, Honda's TJP-equipped Legend sedan was released in limited quantities in Japan. HRL 9 evaluation activities would include ongoing human systems monitoring to ensure that the intended levels of performance are achieved. Human systems experts should be involved in the design of driver training offered through the manufacturer or through leasing agencies.

CONCLUSION

HRLs are an important tool for evaluating and communicating about a technology's readiness for human use. Rapid advances in automated driving systems (ADS) have motivated the development of shared language for classifying these systems and guidance to ensure clear and consistent safety standards and communication among stakeholders; HRLs are another important contribution to this effort. Further, ANSI/HFES 400-2021 provides a critical tool for supporting the National Highway Traffic Safety Association (NHTSA) Automated Vehicle (AV) 2.0's recommended self-assessment. This (currently) voluntary self-assessment is designed to support those involved in

ADS testing and deployment to demonstrate to the public that they are: "(1) considering the safety aspects of ADSs; (2) communicating and collaborating with DOT; (3) encouraging the self-establishment of industry safety norms for ADSs; and (4) building public trust, acceptance, and confidence through transparent testing and deployment of ADSs" (NHTSA, 2017, p. 16). Achieving these goals, however, requires a common language for describing human readiness and clear guidance on the types of milestones that must be met before an automated driving feature is deemed ready for operational use. In support of this, the Human Factors and Ergonomics Society recently released Policy Statement on Autonomous and Semi-Autonomous Vehicles (2.0) that advocates for NHTSA to require human factors assessment through all steps of the design, development, and deployment and that HRLs are adopted as a mechanism for assessing and communicating AV readiness for human use (HFES, 2022).

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