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(54) **SYSTEMS AND METHODS FOR ENHANCING OPERATOR VIGILANCE**

(71) Applicant: **Woven by Toyota, Inc.**, Tokyo (JP)

(72) Inventors: **Manuel Ludwig Kuehner**, Mountain View, CA (US); **Hiroshi Yasuda**, San Francisco, CA (US); **Gyanendra Sharma**, Foster City, CA (US)

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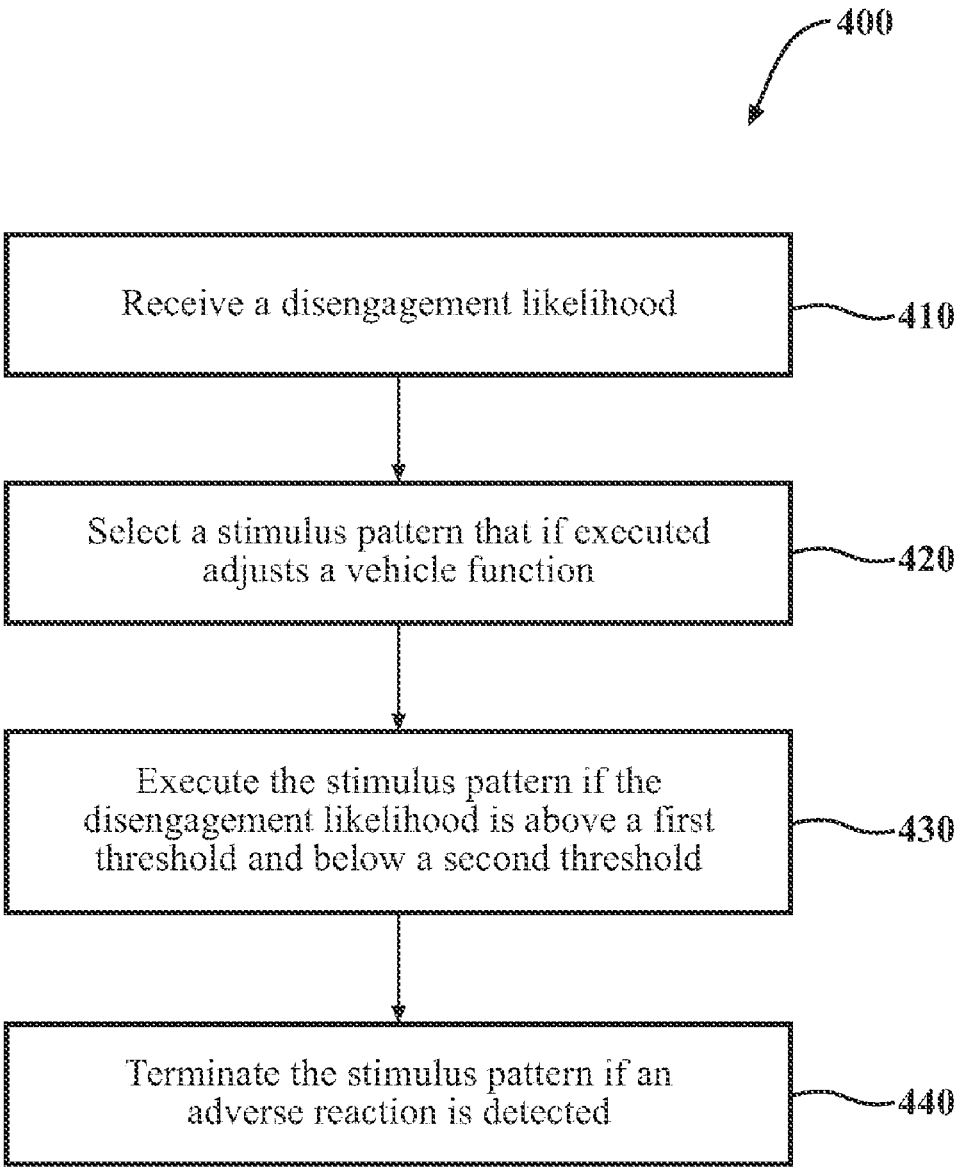
(57) **ABSTRACT**

System, methods, and other embodiments described herein relate to enhancing operator vigilance without causing an adverse reaction. In one embodiment, a method includes receiving a disengagement likelihood; selecting a stimulus pattern that if executed adjusts a vehicle function; and executing the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.



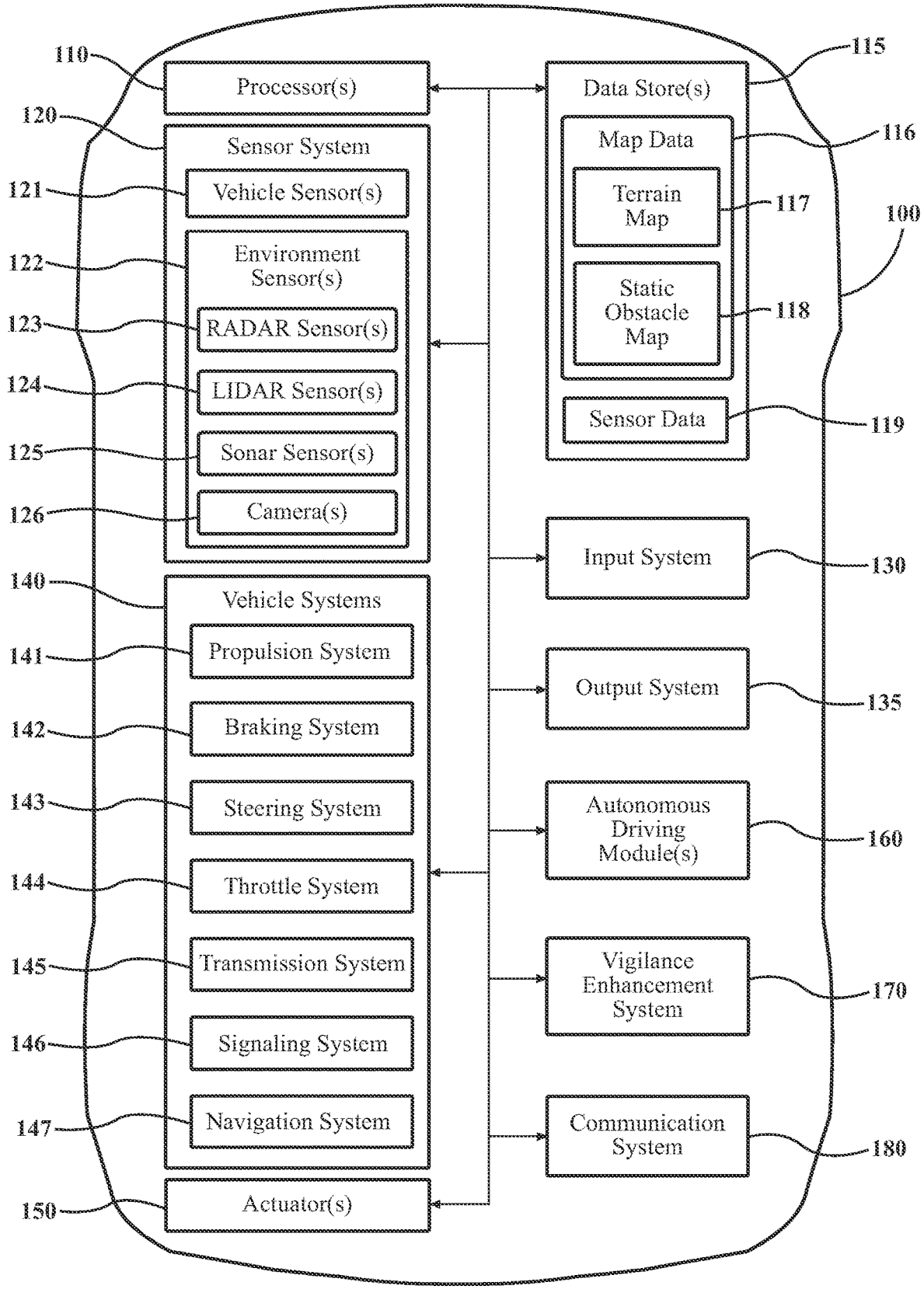

110
Processor(s)
115
Data Store(s)
120
Sensor System
Map Data
116
121
Vehicle Sensor(s)
Terrain Map
117
100
122
Environment Sensor(s)
Static Obstacle Map
118
123
RADAR Sensor(s)
124
LIDAR Sensor(s)
Sensor Data
119
125
Sonar Sensor(s)
126
Camera(s)
Input System
130
140
Vehicle Systems
141
Propulsion System
Output System
135
142
Braking System
143
Steering System
Autonomous Driving Module(s)
160
144
Throttle System
145
Transmission System
Vigilance Enhancement System
170
146
Signaling System
147
Navigation System
Communication System
180
150
Actuator(s)

FIG. 1

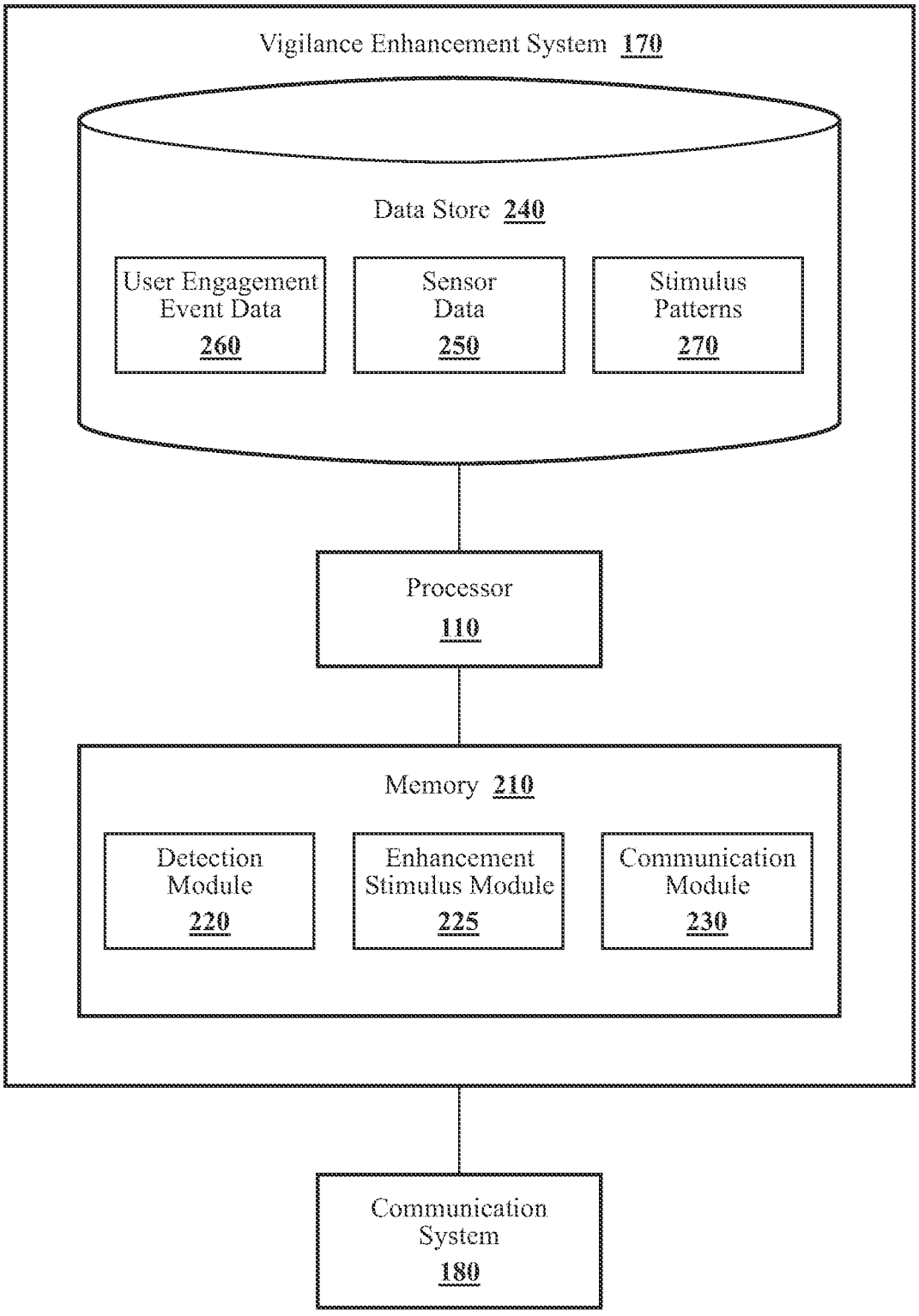

Vigilance Enhancement System 170
Data Store 240
User Engagement Event Data 260
Sensor Data 250
Stimulus Patterns 270
Processor 110
Memory 210
Detection Module 220
Enhancement Stimulus Module 225
Communication Module 230
Communication System 180

FIG. 2

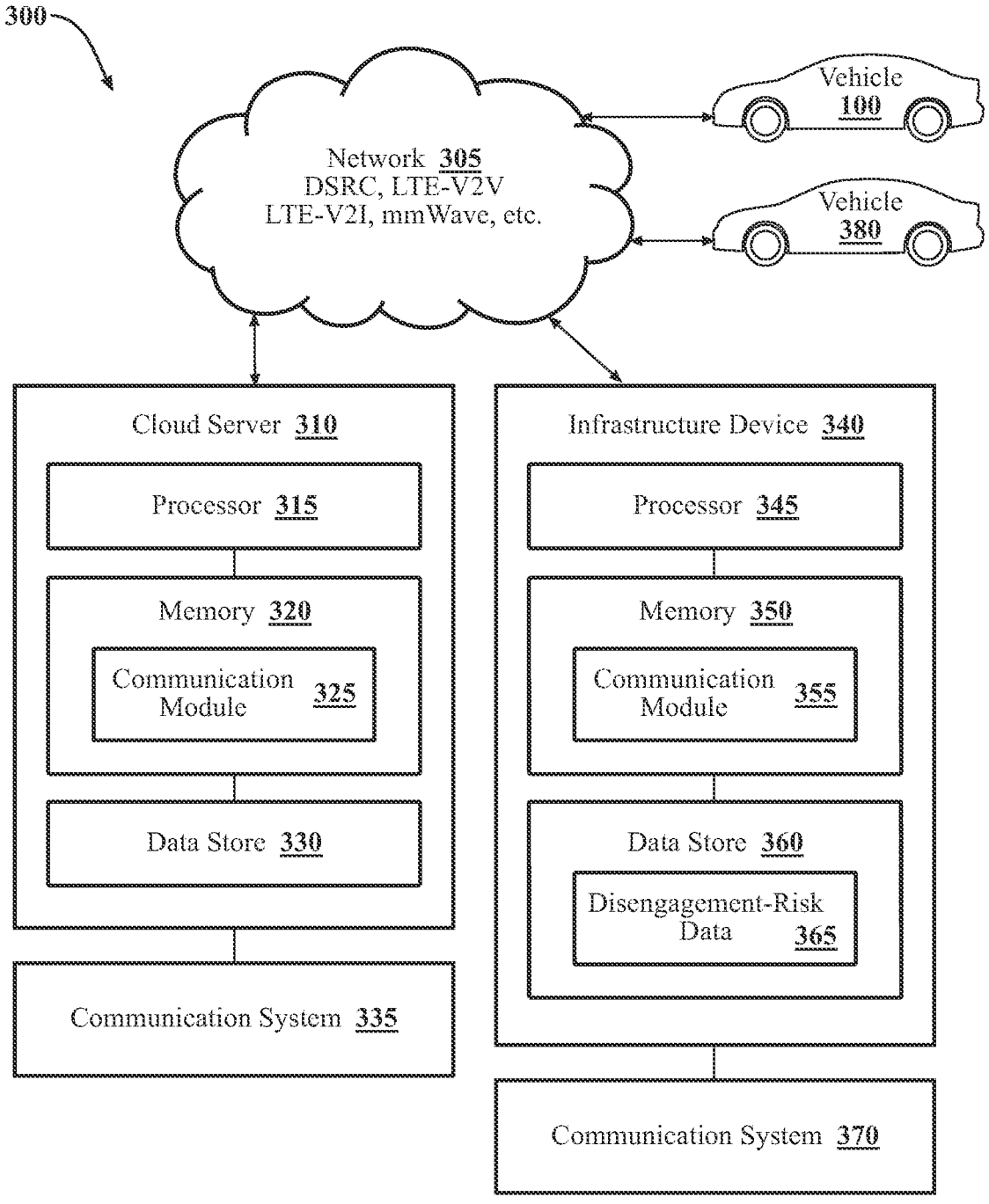

300
Network 305
DSRC, LTE-V2V
LTE-V2I, mmWave, etc.
Vehicle
100
Vehicle
380
Cloud Server 310
Processor 315
Memory 320
Communication Module 325
Data Store 330
Communication System 335
Infrastructure Device 340
Processor 345
Memory 350
Communication Module 355
Data Store 360
Disengagement-Risk Data 365
Communication System 370

FIG. 3

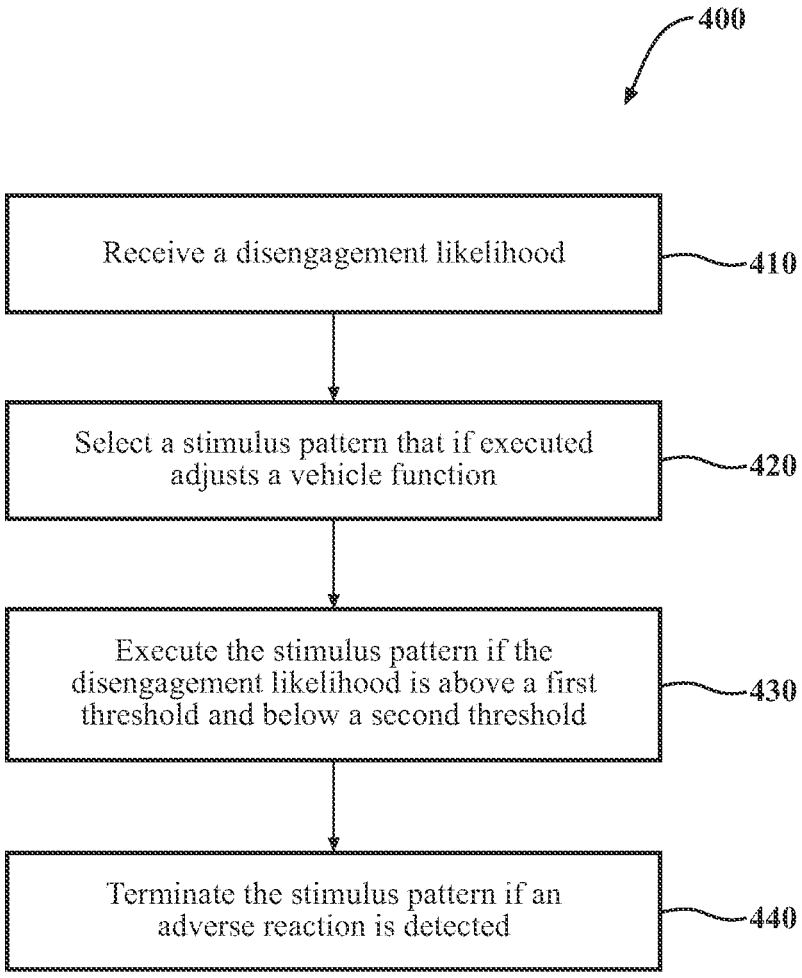

400
Receive a disengagement likelihood
410
Select a stimulus pattern that if executed adjusts a vehicle function
420
Execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold
430
Terminate the stimulus pattern if an adverse reaction is detected
440

FIG. 4

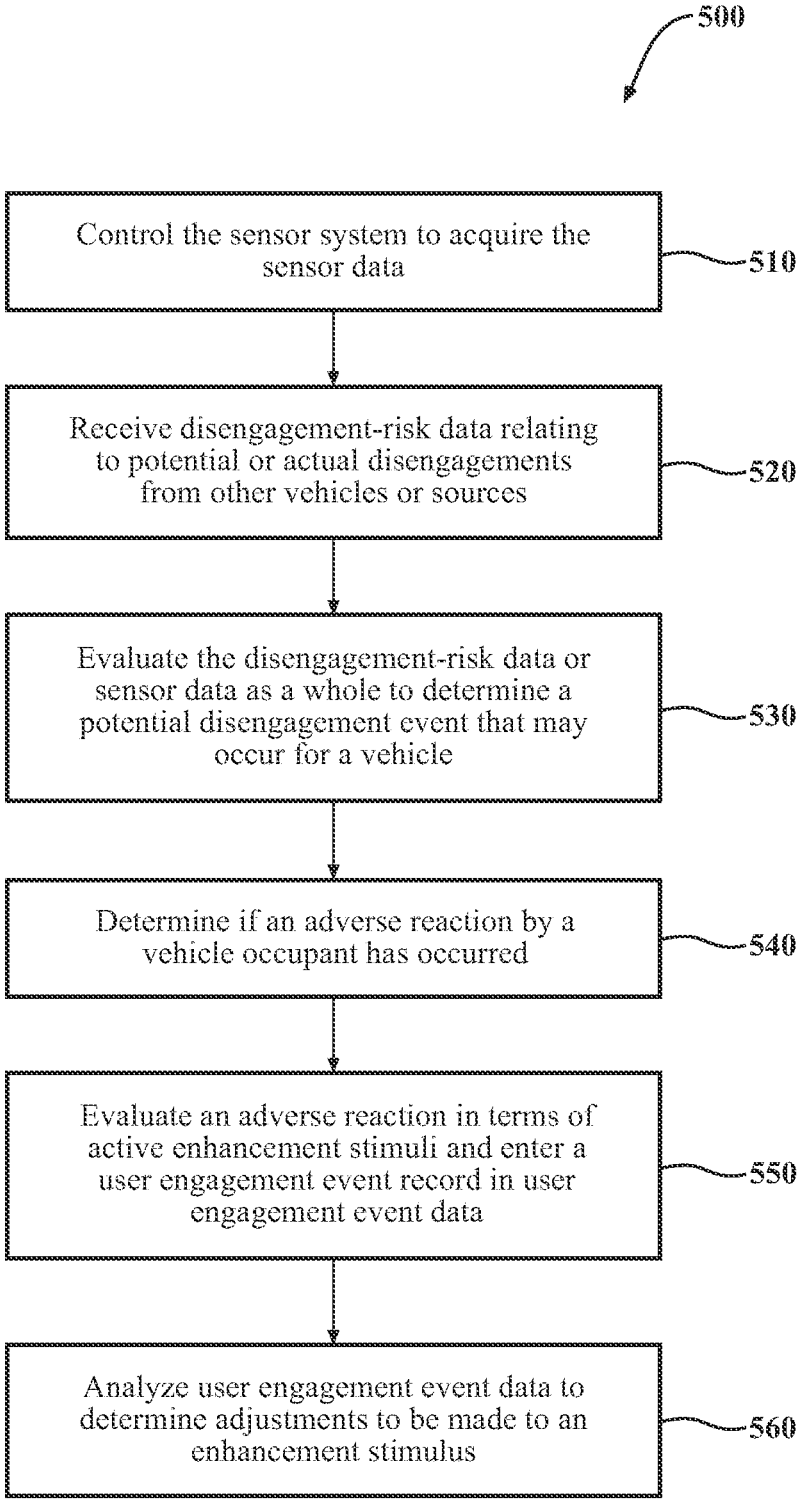

500
Control the sensor system to acquire the sensor data
510
Receive disengagement-risk data relating to potential or actual disengagements from other vehicles or sources
520
Evaluate the disengagement-risk data or sensor data as a whole to determine a potential disengagement event that may occur for a vehicle
530
Determine if an adverse reaction by a vehicle occupant has occurred
540
Evaluate an adverse reaction in terms of active enhancement stimuli and enter a user engagement event record in user engagement event data
550
Analyze user engagement event data to determine adjustments to be made to an enhancement stimulus
560

FIG. 5

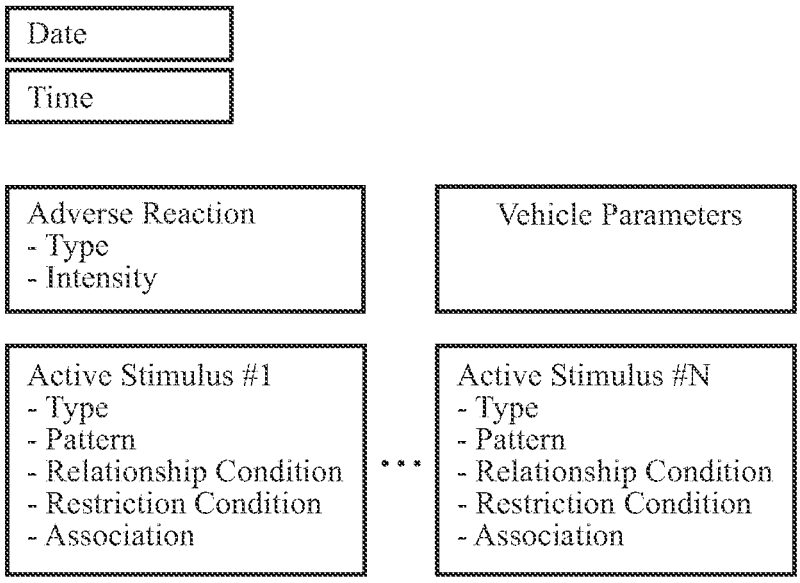

Date
Time
Adverse Reaction
- Type
- Intensity
Vehicle Parameters
Active Stimulus #1
- Type
- Pattern
- Relationship Condition
- Restriction Condition
- Association
• • •
Active Stimulus #N
- Type
- Pattern
- Relationship Condition
- Restriction Condition
- Association

FIG. 6

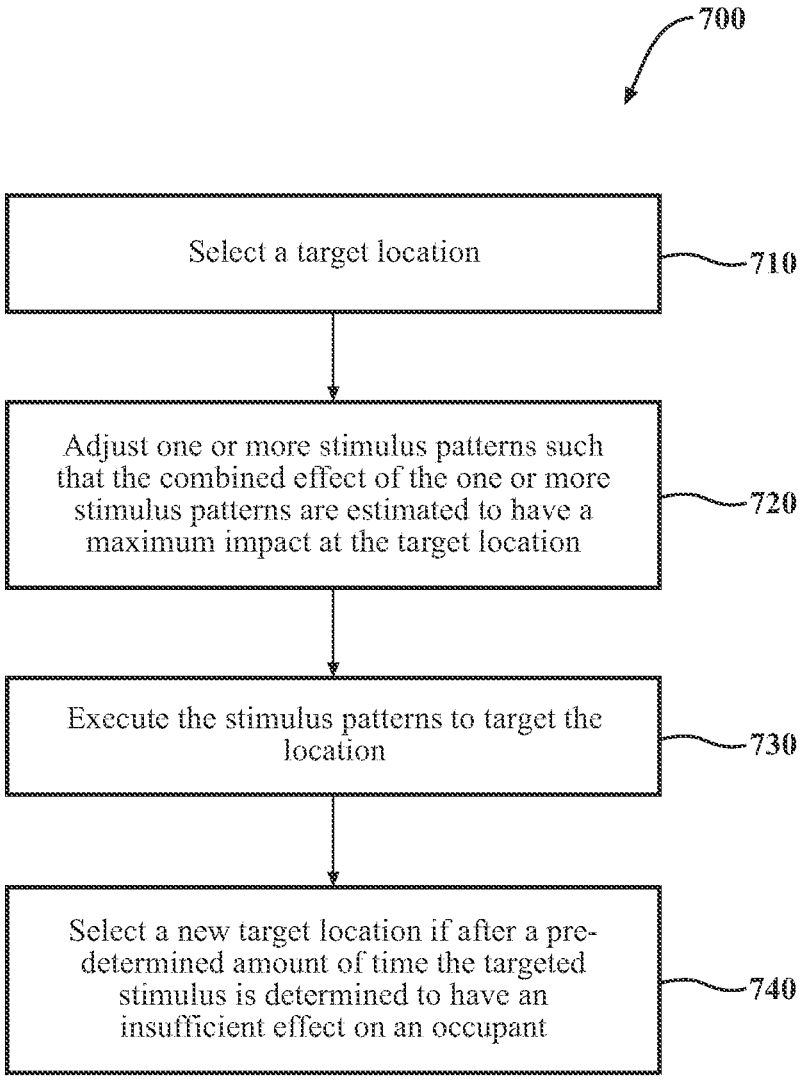

700
Select a target location
710
Adjust one or more stimulus patterns such that the combined effect of the one or more stimulus patterns are estimated to have a maximum impact at the target location
720
Execute the stimulus patterns to target the location
730
Select a new target location if after a pre-determined amount of time the targeted stimulus is determined to have an insufficient effect on an occupant
740

FIG. 7

SYSTEMS AND METHODS FOR ENHANCING OPERATOR VIGILANCE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of U.S. Non-Provisional application Ser. No. 18/095,206, filed on, Jan. 10, 2023, which is herein incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The subject matter described herein relates, in general, to operator vigilance, and, more particularly, to enhancing operator vigilance without causing an adverse reaction.

BACKGROUND

[0003] Vehicles may be equipped with systems or methods for measuring operator vigilance. For example, a driver monitoring system may determine if a driver is fatigued or otherwise lacking sufficient vigilance for a desired task. In particular, when a disengagement event occurs necessitating takeover from autonomous mode, a driver monitoring system may seek to provoke a driver into a higher state of operator vigilance sufficient to resume manual driving. Generally, such provocations look for a desired response indicating such a higher state of operator vigilance, such as the driver taking hold of the steering wheel, the driver's eyes looking out on the road, or the driver moving to a more upright driving position. Further, a lack of a reaction is often taken as a negative indication of operator vigilance necessitating further provocation.

SUMMARY

[0004] In one embodiment, example systems and methods relate to a manner of enhancing operator vigilance without causing an adverse reaction are disclosed.

[0005] In one embodiment, a vigilance enhancement system for a vehicle is disclosed. The vigilance enhancement system includes one or more processors and a memory communicably coupled to the one or more processors. The memory stores instructions that when executed by the one or more processors cause the one or more processors to receive a disengagement likelihood; select a stimulus pattern that if executed adjusts a vehicle function; and execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

[0006] In one embodiment, a non-transitory computer-readable medium for enhancing operator vigilance and including instructions that when executed by one or more processors cause the one or more processors to perform one or more functions is disclosed. The instructions include instructions to receive a disengagement likelihood; select a stimulus pattern that if executed adjusts a vehicle function; and execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

[0007] In one embodiment, a method for enhancing operator vigilance is disclosed. In one embodiment, the method includes receiving a disengagement likelihood; selecting a stimulus pattern that if executed adjusts a vehicle function; and executing the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] The accompanying drawings, which are incorporated in and constitute a part of the specification, illustrate various systems, methods, and other embodiments of the disclosure. It will be appreciated that the illustrated element boundaries (e.g., boxes, groups of boxes, or other shapes) in the figures represent one embodiment of the boundaries. In some embodiments, one element may be designed as multiple elements or multiple elements may be designed as one element. In some embodiments, an element shown as an internal component of another element may be implemented as an external component and vice versa. Furthermore, elements may not be drawn to scale.

[0009] FIG. **1** illustrates one embodiment of a vehicle within which systems and methods disclosed herein may be implemented.

[0010] FIG. **2** illustrates one embodiment of a user vigilance system that is associated with using stimulus patterns to enhance operator vigilance.

[0011] FIG. **3** illustrates one embodiment of a cloud computing environment within which the systems and methods described herein may operate.

[0012] FIG. **4** illustrates one embodiment of a disengagement-risk management method.

[0013] FIG. **5** illustrates one embodiment of a method for detecting potential disengagement events and adverse reactions.

[0014] FIG. **6** illustrates one embodiment of a user engagement event record.

[0015] FIG. **7** illustrates one embodiment of a method for targeting a user through an enhancement stimulus.

DETAILED DESCRIPTION

[0016] Systems, methods, and other embodiments associated with enhancing user vigilance are disclosed herein. Prior to a disengagement event, it may be desirable to enhance operator vigilance prior to the issuance of a takeover request. However, it is also desirable that the enhancement of operator vigilance prior to a takeover request is less provocative than what may occur after a takeover request. For example, provocations to raise operator vigilance upon a disengagement notification are intentionally obtrusive so as to ensure that a driver is in a proper mental and physical state to takeover driving the vehicle. Given that prior to a disengagement notification, using such obtrusive provocations may act to annoy a driver, systems and methods are disclosed herein regarding subtler stimuli that may act to enhance operator vigilance without requiring driver monitoring systems or causing adverse reactions (e.g., a driver's undesired reaction to such an enhancement stimulus).

[0017] In particular, stimulus patterns for use with enhancement stimulus modules are disclosed herein that may be used to enhance operator vigilance based on a disengagement likelihood. Such a stimulus pattern may contain instructions for seat massage patterns where the intensity, frequency, or location of the massage change based on a disengagement likelihood; seat temperature patterns where the temperature changes based on a disengagement likelihood; cabin temperature patterns where the tem-

perature or other characteristics change based on a disengagement likelihood; seat position patterns where the position or inclination change based on a disengagement likelihood; window control patterns where positioning or transparency changed based on disengagement likelihood; cabin sound patterns where audio parameters change based on disengagement likelihood; and so on. As these stimulus patterns may be adjusted to avoid specific adverse reactions, such an approach is advantageous in that it may allow for enhancing operator vigilance while avoiding a more costly approach based on repeatedly evaluating operator vigilance, mental states, etc.

[0018] Referring to FIG. **1**, an example of a vehicle **100** is illustrated. As used herein, a "vehicle" is any form of motorized transport. In one or more implementations, the vehicle **100** is an automobile. While arrangements will be described herein with respect to automobiles, it will be understood that embodiments are not limited to automobiles. In some implementations, the vehicle **100** may be any robotic device or form of motorized transport that, for example, includes sensors to perceive aspects of the surrounding environment, and thus benefits from the functionality discussed herein associated with using stimulus patterns to enhance user vigilance. As a further note, this disclosure generally discusses the vehicle **100** as traveling on a roadway with surrounding vehicles, which are intended to be construed in a similar manner as the vehicle **100** itself. That is, the surrounding vehicles can include any vehicle that may be encountered on a roadway by the vehicle **100**.

[0019] The vehicle **100** also includes various elements. It will be understood that in various embodiments it may not be necessary for the vehicle **100** to have all of the elements shown in FIG. **1**. The vehicle **100** can have any combination of the various elements shown in FIG. **1**. Further, the vehicle **100** can have additional elements to those shown in FIG. **1**. In some arrangements, the vehicle **100** may be implemented without one or more of the elements shown in FIG. **1**. While the various elements are shown as being located within the vehicle **100** in FIG. **1**, it will be understood that one or more of these elements can be located external to the vehicle **100**. Further, the elements shown may be physically separated by large distances. For example, as discussed, one or more components of the disclosed system can be implemented within a vehicle while further components of the system are implemented within a cloud-computing environment or other system that is remote from the vehicle **100**.

[0020] Some of the possible elements of the vehicle **100** are shown in FIG. **1** and will be described along with subsequent figures. However, a description of many of the elements in FIG. **1** will be provided after the discussion of FIGS. **2-7** for purposes of brevity of this description. Additionally, it will be appreciated that for simplicity and clarity of illustration, where appropriate, reference numerals have been repeated among the different figures to indicate corresponding or analogous elements. In addition, the discussion outlines numerous specific details to provide a thorough understanding of the embodiments described herein. Those of skill in the art, however, will understand that the embodiments described herein may be practiced using various combinations of these elements. In either case, the vehicle **100** includes a vigilance enhancement system **170** that is implemented to perform methods and other functions as disclosed herein relating to enhancing user vigilance via stimulus patterns executed by enhancement stimulus module **225**. As will be discussed in greater detail subsequently, the vigilance enhancement system **170**, in various embodiments, is implemented partially within the vehicle **100**, and as a cloud-based service. For example, in one approach, functionality associated with at least one module of the vigilance enhancement system **170** is implemented within the vehicle **100** while further functionality is implemented within a cloud-based computing system.

[0021] With reference to FIG. **2**, one embodiment of the vigilance enhancement system **170** of FIG. **1** is further illustrated. The vigilance enhancement system **170** is shown as including a processor **110** from the vehicle **100** of FIG. **1**. Accordingly, the processor **110** may be a part of the vigilance enhancement system **170**, the vigilance enhancement system **170** may include a separate processor from the processor **110** of the vehicle **100**, or the vigilance enhancement system **170** may access the processor **110** through a data bus or another communication path. In one embodiment, the vigilance enhancement system **170** includes a memory **210** that stores a detection module **220**, an enhancement stimulus module **225**, and a communication module **230**. The memory **210** is a random-access memory (RAM), read-only memory (ROM), a hard-disk drive, a flash memory, or other suitable memory for storing the modules **220**, **225**, and **230**. The modules **220**, **225**, and **230** are, for example, computer-readable instructions that when executed by the processor **110** cause the processor **110** to perform the various functions disclosed herein. The vigilance enhancement system **170** as illustrated in FIG. **2** is generally an abstracted form of the vigilance enhancement system **170** as may be implemented between the vehicle **100** and a cloud-computing environment.

[0022] With reference to FIG. **2**, the detection module **220** generally includes instructions that function to control the processor **110** to receive data inputs from one or more sensors of the vehicle **100**. The inputs are, in one embodiment, observations of one or more objects in an environment proximate to the vehicle **100** or other aspects about the surroundings. As provided for herein, the detection module **220**, in one embodiment, acquires sensor data **250** that includes at least camera images. In further arrangements, the detection module **220** acquires the sensor data **250** from further sensors such as a radar **123**, a LiDAR **124**, and other sensors as may be suitable for identifying vehicles and locations of the vehicles. In some arrangements, the detection module **220** acquires the sensor data **250** from further sensors such as weight sensors, movement sensors, grip sensors, force sensors, driver monitoring systems, EEG systems, capacitive sensors, and other sensors as may be suitable for observing the behavior of occupants within a vehicle.

[0023] Accordingly, the detection module **220**, in one embodiment, controls the respective sensors to provide the data inputs in the form of the sensor data **250**. Additionally, while the detection module **220** is discussed as controlling the various sensors to provide the sensor data **250**, in one or more embodiments, the detection module **220** can employ other techniques to acquire the sensor data **250** that are either active or passive. For example, the detection module **220** may passively sniff the sensor data **250** from a stream of electronic information provided by the various sensors to further components within the vehicle **100**. Moreover, the detection module **220** can undertake various approaches to fuse data from multiple sensors when providing the sensor

data **250** or from sensor data acquired over a wireless communication link (e.g., v2v) from one or more of the surrounding vehicles. Thus, the sensor data **250**, in one embodiment, represents a combination of perceptions acquired from multiple sensors.

[0024] In addition to locations of surrounding vehicles, the sensor data **250** may also include, for example, information about lane markings, and so on. Moreover, the detection module **220**, in one embodiment, controls the sensors to acquire the sensor data **250** about an area that encompasses 360 degrees about the vehicle **100** in order to provide a comprehensive assessment of the surrounding environment. Of course, in alternative embodiments, the detection module **220** may acquire the sensor data about a forward direction alone when, for example, the vehicle **100** is not equipped with further sensors to include additional regions about the vehicle or the additional regions are not scanned due to other reasons (e.g., unnecessary due to known current conditions).

[0025] Moreover, in one embodiment, the vigilance enhancement system **170** includes the database **240**. The database **240** is, in one embodiment, an electronic data structure stored in the memory **210** or another data store and that is configured with routines that can be executed by the processor **110** for analyzing stored data, providing stored data, organizing stored data, and so on. Thus, in one embodiment, the database **240** stores data used by the modules **220**, **225**, and **230** in executing various functions. In one embodiment, the database **240** includes the sensor data **250** along with, for example, metadata that characterize various aspects of the sensor data **250**. For example, the metadata can include location coordinates (e.g., longitude and latitude), relative map coordinates or tile identifiers, time/date stamps from when the separate sensor data **250** was generated, and so on. In one embodiment, the database **240** further includes user engagement event data **260** and stimulus patterns **270** as described herein.

[0026] The detection module **220**, in one embodiment, is further configured to perform additional tasks beyond controlling the respective sensors to acquire and provide the sensor data **250**. For example, the detection module **220** may include instructions that cause the processor **110** to determine if an adverse reaction defining a user engagement event has occurred.

[0027] An adverse reaction may include any detectable action by an occupant of a vehicle that may be interpreted as a response to an enhancement stimulus (e.g., a stimulus pattern being executed by an enhancement stimulus module on a vehicle system as described herein). For example, an adverse reaction may include an occupant interacting with a steering wheel, an interactive screen, gas or brake pedals, seat controls, dashboard controls, or any other vehicle user interface in response to an enhancement stimulus. In some embodiments, the finding of an adverse reaction may require that a relationship condition, such as one that may be specified in a stimulus pattern, be satisfied between the enhancement stimulus and a user response. For example, the relationship condition may be that the response is an action by the user affecting the operation of the enhancement stimulus, such as turning off or otherwise adjusting the magnitude, modulation, location, or other user-controlable characteristics of a vehicle system in order to affect the operation of an active enhancement stimulus. In some embodiments, the finding of an adverse reaction may also require satisfaction of time-based restrictions, such as that the user response occured within a time frame associated with a change in the enhancement stimulus made by enhancement stimulus module **225**. In some embodiments, a finding of an adverse reaction may also require that a user response occur within a time frame prior to a disengagement warning or takeover request.

[0028] In some embodiments, the detection module **220** may also include instructions that cause the processor **110** to determine positive or negative associations for a user engagement event record based on the adverse reaction and the enhancement stimuli in effect. For example, if an occupant grabs the steering wheel while a seat position/incline enhancement stimulus is being applied, a positive association with respect to the seat position/incline enhancement stimulus may be recorded, along with the adverse reaction, in the user engagement event record.

[0029] As another example, a vehicle occupant may be subject to multiple enhancement stimuli (e.g., based on temperature, vibration, and seat position adjustments) but only acts to turn off massage. In such a situation, the detection module **220** may record in a user engagement event record that a positive association exists between the adverse reaction and the massage-based enhancement stimulus, but that one or more negative associations exists between the adverse reaction and the temperature-based and seat-position-based enhancement stimuli. Further, in some embodiments, the values of the negative or positive associations recorded in a user engagement event record may depend on the type of adverse reaction, the magnitude of the adverse reaction, or other measurements giving an indication of the strength of the adverse reaction detected.

[0030] For example, if a user response is to gently engage the steering wheel in response to a first enhancement stimulus as opposed to suddenly grasping the steering wheel with intense force in response to a second enhancement stimulus, then different values for indicating positive associations between the first and second enhancement stimuli may be implemented (e.g., that the positive association with the first enhancement stimulus has a smaller magnitude than the positive association with the second enhancement stimulus). As another example, when a vehicle occupant displays a high level of sensitivity to a particular enhancement stimulus (e.g., frequently having an adverse reaction to massage-based enhancement stimulus), a higher positive association may be assigned even if the user response is mild (e.g., merely turning off the massage-based stimulus) due to the occupant's higher-than-usual frequency of adverse reactions arising from massage-based stimulus. In some embodiments, a specific value (e.g., "0") may be used with respect to the negative or positive association to indicate a lack of a relationship between an enhancement stimulus and an adverse reaction.

[0031] In some embodiments, the detection module **220** may also include information in a user engagement event record associated with an adverse reaction, such as for each active enhancement stimulus: the stimulus pattern(s) in use; the type of stimulus (e.g., massage, seat temperature); the time since the last adjustment of the enhancement stimulus; the nature of the last adjustment of the enhancement stimulus; any restriction conditions as described below affecting the stimulus; the termination or not of the enhancement stimulus; or any adjustment of the enhancement stimulus subsequent to the adverse reaction. In addition, the user engagement event record may further contain additional

context relating to vehicle performance or its environment, such as recent changes in a likelihood of disengagement, occurrence of actual disengagement, vehicle speed or location, etc.

[0032] In one embodiment, the enhancement stimulus module **225** generally includes instructions that function to control the processor **110** or collection of processors in the cloud-computing environment **300** to receive one or more stimulus patterns **270** for implementing enhancement stimuli. Stimulus patterns **270** may contain information that when executed causes enhancement stimulus module **225** to alter one or more characteristics of a system under the control of vehicle systems **140** (e.g., a seat massage system, a seat temperature system, a cabin temperature system, seat position/incline system, seat massage system, a window transparency system, a cabin audio system, a window positioning system). Moreover, the adjustments made by enhancement stimulus module **225** may vary in proportion to an estimate of a disengagement likelihood as described herein.

[0033] With respect to a stimulus pattern affecting a seat massage system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off massage functions; change the pattern or location of massage functions; or change the intensity or frequency of the massage functions. Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a seat massage system may be that the response detected must involve a user-requested change to the operation of the seat massage system.

[0034] With respect to a stimulus pattern affecting a seat temperature system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off seat heating or cooling functions; change the pattern or location of seat heating or cooling functions; or change the intensity or frequency of the seat heating or cooling functions (e.g., increasing or decreasing the heating or cooling; varying fan speed or alternating between hotter and cooler air in ventilated/cooled seats). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a seat temperature system may be that the response detected must involve a user-requested change to the operation of the seat temperature system.

[0035] With respect to a stimulus pattern affecting a cabin temperature system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off cabin temperature functions; change the pattern or location of cabin temperature functions (e.g., switch from dashboard vents to floor vents); or change the intensity or frequency of the cabin temperature functions (e.g., increasing or decreasing the heating or cooling; varying fan speeds; alternating between hotter and cooler air). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a cabin temperature system may be that the response detected must involve a user-requested change to the operation of the cabin temperature system.

[0036] With respect to a stimulus pattern affecting a seat position/incline system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off seat position/incline functions (e.g., turn off a recline mode; turn on a restricted mode limiting seat position or incline); or change location settings of position/incline functions (e.g., adjusting the x, y, or z axes of the seat; changing the incline of the seat). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a seat position/incline system may be that the response detected must involve a user-requested change to the operation of the seat position/incline system.

[0037] With respect to a stimulus pattern affecting a seat massage system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off massage functions; change the pattern or location of massage functions; or change the intensity or frequency of the massage functions. Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a seat massage system may be that the response detected must involve a user-requested change to the operation of the seat massage system.

[0038] With respect to a stimulus pattern affecting a window transparency system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off window transparency functions; change the pattern or location of window transparency functions (e.g., change from one window transparency mode to another; remove window transparency from the windshield); or change the intensity or frequency of the window transparency functions (e.g., reduce/increase transparency; modulate transparency). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a window transparency system may be that the response detected must involve a user-requested change to the operation of the window transparency system.

[0039] With respect to a stimulus pattern affecting a cabin sound system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off cabin sound functions (e.g., turn on or off a white noise generator, artificial engine noise, or noise suppression); change the pattern or location of cabin sound functions (e.g., adjusting speaker balance; adding acoustic disturbances to cabin sounds); or change the intensity or frequency of the cabin sound functions (e.g., increasing/decreasing volume; altering the frequency of white noise being generated). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a cabin sound system may be that the response detected must involve a user-requested change to the operation of the cabin sound system.

[0040] With respect to a stimulus pattern affecting a window positioning system, such a stimulus pattern when executed by the enhancement stimulus module **225** may turn on or off window positioning functions (e.g., turn off driver control only mode); or change the pattern or location of window positioning functions (e.g., retract or open windows, window coverings, moonroof/sunroof, etc. to a new position; adjust window positions to create turbulence). Further, a relationship condition for determining an adverse reaction to a stimulus pattern affecting a window positioning system may be that the response detected must involve a user-requested change to the operation of the window positioning system.

[0041] In some embodiments, a stimulus pattern may contain instructions to modulate a vehicle system parameter, such as fan speed, temperature setting, lighting intensity, and so on. For example, a ventilation fan may be set to operate at a specific speed by a vehicle system, which is then further modified by a stimulus pattern (via enhancement stimulus module **225**) to modulate the fan speed according to a sinusoidal pattern having a specified magnitude and frequency. Such a time-varying stimulus pattern may be rep-

resented by periodic waveforms (e.g., sinusoidal, sawtooth, square wave), where such waveforms may by defined by a magnitude, frequency, time, or other variables. Such a time-varying stimulus pattern may also be represented by random functions, aperiodic waveforms, Fourier transforms, or other techniques known in the art for representing functions or waveforms. In some embodiments, stimulus patterns may instruct multiple components of a vehicle system via the enhancement stimulus module **225** to act the same, while in other embodiments such components may be instructed to act in opposition to each other. In some embodiments, a stimulus pattern may pose a different set of instructions for the adjustments to be performed on each component that the stimulus pattern affects.

[0042] In some embodiments, a stimulus pattern may contain information modifying the execution of the stimulus pattern by the enhancement stimulus module **225**, such as a duration to perform the stimulus pattern upon being triggered; a duty cycle for turning on and off the stimulus pattern within a period of time (e.g., 50%); or restriction conditions on the use of the stimulus pattern based on the vehicle occupant, vehicle speed, vehicle location, road surface types, local weather environment, or other conditions that must be satisfied before the stimulus pattern may be used. For example, some stimulus patterns may only be used with specific vehicle occupants; below or above certain vehicle speeds; at the start or end of a journey; in locations of particular concern or interest (e.g., schools, construction zones, parking lots, driveways); on specific road surfaces (e.g., only gravel); on dry roads only; in snow conditions only; and so on. In this manner, the use of restrictive conditions in the stimulus patterns may be used to enhance the awareness of the driver by providing a subtle suggestion related to a particular experience (e.g., arriving home, driving through a school zone, current weather conditions) only when such restriction conditions are satisfied.

[0043] The enhancement stimulus module **225** may also generally include instructions that function to control the processor **110** or collection of processors in the cloud-computing environment **300** to select at least one stimulus pattern. For example, based on a potential disengagement event, the enhancement stimulus module **225** may select a stimulus pattern such as a sinusoidal waveform that varies the magnitude of a seat massage function. As another example, based on information obtained from the potential disengagement event (e.g., risk of handoff in school zone), enhancement stimulus module **225** may select a specific pattern that is allowed under such a condition (e.g., a specific seat position/incline stimulus pattern used only when in a school zone). As another example, enhancement stimulus module **225** may select a stimulus pattern based on information that results in lower instances of adverse reactions (e.g., based on negative/positive associations recorded in user engagement event data **260**) or a greater reduction in operator response time after a disengagement notification. In some embodiments, vehicle operators may be able to select, arrange, or prohibit stimulus patterns generally or for specific contexts, such as through an interactive display or app.

[0044] The enhancement stimulus module **225** may also generally include instructions that function to control the processor **110** or collection of processors in the cloud-computing environment **300** to execute the at least one stimulus pattern. In one embodiment, the enhancement stimulus module **225** applies the at least one stimulus pattern by carrying out the instructions in the stimulus pattern to adjust one or more vehicle systems. In some embodiments, the execution of the stimulus pattern by enhancement stimulus module **225** is terminated if an adverse reaction is detected (e.g., by detection module **220**). Alternatively, the termination may only occur if a specific adverse reaction is detected (e.g., operator's hands on steering wheel; turning off massage function; closing a window). The adverse reactions that result in termination of the stimulus pattern may be pre-determined or adjusted over time (e.g., based on negative/positive associations recorded in user engagement event data **260**). In some embodiments, a stimulus pattern may contain a set of allowed conditions for termination of such a stimulus pattern with respect to potential adverse reactions. In some embodiments, a stimulus pattern may also include instructions for the desired method of termination for the stimulus pattern (e.g., a ramp function determining the duration and rate of decay for a return to normal vehicle operation).

[0045] In some embodiments, even if an adverse reaction is not detected, the enhancement stimulus module **225** may cease executing a stimulus pattern if the likelihood of disengagement for a potential disengagement event exceeds a pre-determined threshold. For example, such a pre-determined threshold may be set to the same value as that for issuing a disengagement notification. In some embodiments, the pre-determined threshold for a first stimulus pattern may be set lower than that of a second stimulus pattern, such that enhancement stimulus module **225** switches to a more aggressive stimulus pattern prior to an actual disengagement notification. For example, enhancement stimulus module **225** may start with a sinusoidal stimulus pattern when the likelihood of disengagement is 0.5, then switch to a sawtooth stimulus pattern when the likelihood of disengagement is 0.6, and finally terminate the sawtooth stimulus pattern and issue a disengagement notification when the likelihood of disengagement reaches 0.7. In further embodiments where different stimulus patterns are used across a range of likelihood of disengagements, enhancement stimulus module **225** may also interpolate between the stimulus patterns. Thus, with respect to the immediate example provided above, the closer the likelihood of disengagement approaches 0.6 from below, the more the initial sinusoidal stimulus pattern may be adjusted by enhancement stimulus module **225** to take on the characteristics of the sawtooth pattern.

[0046] In some embodiments, enhancement stimulus module **225** may use one or more stimulus patterns to target a specific vehicle occupant. For example, a stimulus pattern executed by enhancement stimulus module **225** may only adjust parameters affecting vehicle systems in a particular location (e.g., only adjusting driver's seat massage system). In some embodiments, a combination of stimulus patterns may be used such that the disturbance generated by the combined effect of the stimulus patterns is greatest at a specific location in vehicle **100**. For example, multiple stimulus patterns may be directed to change the temperature in the area of the driver while reducing window transparency and enabling driver seat massage. In some embodiments, the combined effect of the stimulus patterns may be evaluated and adjusted by enhancement stimulus module **225** based on information obtained via sensor data **250** to better achieve the targeting effect. In some embodiments, enhancement stimulus module **225** may shift the desired targeting process

to a different location. For example, if the targeted enhancement stimulus is determined not to have a sufficient effect on a first occupant (e.g., the driver remains still for 10 seconds), enhancement stimulus module **225** may switch the target location to another location (e.g., the front passenger).

[0047] In one embodiment, the communication module **230** generally includes instructions that function to control the processor **110** or collection of processors in the cloud-computing environment **300** to collect information potentially affecting an estimated probability of potential disengagement by vehicle **100**. For instance, FIG. **3** illustrates one example of a cloud-computing environment **300** that may be implemented along with the vigilance enhancement system **170**.

[0048] With reference to FIG. **3**, vehicle **100** may be connected to a network **305**, which allows for communication between vehicle **100** and cloud servers (e.g., cloud server **310**), infrastructure devices (e.g., infrastructure device **340**), other vehicles (e.g., vehicle **380**), and any other systems connected to network **305**.

[0049] The cloud server **310** is shown as including a processor **315** that may be a part of the vigilance enhancement system **170** through network **305** via communication unit **335**. In one embodiment, the cloud server **310** includes a memory **320** that stores a communication module **325**. The memory **320** is a random-access memory (RAM), read-only memory (ROM), a hard-disk drive, a flash memory, or other suitable memory for storing the module **325**. The module **325** is, for example, computer-readable instructions that when executed by the processor **315** cause the processor **315** to perform the various functions disclosed herein. Moreover, in one embodiment, cloud server **310** includes the database **330**. The database **330** is, in one embodiment, an electronic data structure stored in the memory **320** or another data store and that is configured with routines that can be executed by the processor **315** for analyzing stored data, providing stored data, organizing stored data, and so on.

[0050] The infrastructure device **340** is shown as including a processor **345** that may be a part of the vigilance enhancement system **170** through network **305** via communication unit **370**. In one embodiment, the infrastructure device **340** includes a memory **350** that stores a communication module **355**. The memory **350** is a random-access memory (RAM), read-only memory (ROM), a hard-disk drive, a flash memory, or other suitable memory for storing the module **355**. The module **355** is, for example, computer-readable instructions that when executed by the processor **345** cause the processor **345** to perform the various functions disclosed herein. Moreover, in one embodiment, infrastructure device **340** includes the database **360**. The database **360** is, in one embodiment, an electronic data structure stored in the memory **350** or another data store and that is configured with routines that can be executed by the processor **345** for analyzing stored data, providing stored data, organizing stored data, and so on. In one embodiment, the database **360** includes the disengagement-risk data **365** along with, for example, metadata that characterize various aspects of the disengagement-risk data **365**. For example, the metadata can include location coordinates (e.g., longitude and latitude), relative map coordinates or tile identifiers, time/date stamps from when the disengagement-risk data **365** was generated, and so on.

[0051] Accordingly, in addition to information obtained from sensor data **250**, communication module **230** may obtain disengagement datasets from other vehicles (e.g., from vehicle **380** via network **305**), where the disengagement datasets may include information from potential disengagement events and actual disengagement events. In some embodiments, potential disengagement events may not be collected if the likelihood of disengagement associated with the potential disengagement event did not exceed a pre-determined threshold (e.g., **0.5**). In some embodiments, the pre-determined threshold for not collecting potential disengagement events may be adjusted based on vehicle parameters (e.g., speed, location), vehicle environment (e.g., highway, construction zone, school zone, sidewalk), or other relevant factors. For example, in higher-risk environments where additional information about lower-probability potential disengagement events are desired, such as a construction or school zone, the pre-determined threshold may be decreased.

[0052] In various embodiments, potential or actual disengagement data may include information as to vehicle parameters and vehicle environment at the time the potential disengagement was sufficiently likely to occur (e.g., based on a pre-determined threshold) or when the actual disengagement occurred. In addition, further vehicle parameters and vehicle environment information before and after such points in time may also be included where it is relevant to evaluation of the potential or actual cause of disengagement. In some embodiments, disengagement datasets may include information outside the bounds of a vehicle's parameters or environment information, such as infrastructure-based, satellite-based, or other extrinsic sources of data found to be associated with potential or actual disengagements, such as weather data, emergency information, construction data, traffic data, and so on along or near the path of travel that may be obtained from non-vehicular sources (e.g., from cloud server **310** or infrastructure device **340**).

[0053] Additional aspects of a method for using stimulus patterns to enhance operator vigilance will be discussed in relation to FIG. **4**. FIG. **4** illustrates a flowchart of a method **400** that is associated with handling a stimulus pattern with respect to affecting vehicle operation. Method **400** will be discussed from the perspective of the vigilance enhancement system **170** of FIGS. **1** and **2**. While method **400** is discussed in combination with the vigilance enhancement system **170** it should be appreciated that the method **400** is not limited to being implemented within the vigilance enhancement system **170** but is instead one example of a system that may implement the method **400**.

[0054] At **410**, enhancement stimulus module **225** may receive a disengagement likelihood. For example, detection module **220** as described with respect to method **500** may determine one or more potential disengagement events for vehicle **100** based on sensor data **250**, including any disengagement-risk data contained therein, and an associated disengagement likelihood for each potential disengagement event. Upon completing the determination of a potential disengagement event and a corresponding disengagement likelihood, detection module **220** may then send such information to enhancement stimulus module **225** (e.g., via communication module **230** or sensor data **250**).

[0055] In some embodiments, enhancement stimulus module **226** may receive the disengagement likelihood associated with a potential disengagement event from an external source, such as an infrastructure device monitoring vehicle **100** or the road.

[0056] At **420**, enhancement stimulus module **225** may select a stimulus pattern that if executed adjusts a vehicle function. For example, enhancement stimulus module **225** may select a stimulus pattern affecting seat massage controls of the driver. As another example, enhancement stimulus module **225** may select one or more stimulus patterns to be used when specific conditions are met, such as a stimulus pattern to be used to indicate high-risk areas (e.g., school zones, construction zones), a stimulus pattern to indicate geographic events (e.g., impending arrival at a destination, transition from a limited access road to local roads), a stimulus pattern to indicate changes in environmental conditions (e.g., wind, rain, snow), and so on. In this manner, enhancement stimulus module **225** may select stimulus patterns that subtly enhance operator vigilance as to a transition that may occur or is occurring. For example, a stimulus pattern prior to the vehicle returning home may subtly engage the occupant's attention toward preparing for arrival.

[0057] In some embodiments, enhancement stimulus module **225** may select stimulus patterns to be used in accordance with information provided to enhancement stimulus module **225**, such as a type of enhancement stimulus requested, vehicle/environment conditions, potential occupant identity and locations, etc. In some embodiments, the selection of one or more stimulus patterns may be pre-determined, while in other embodiments the selection of one or more stimulus patterns may be adjusted over time. For example, stimulus patterns having a high positive association with one or more adverse reactions may be removed from the selection and other stimulus patterns having a negative or low positive association selected instead.

[0058] In some embodiments, enhancement stimulus module **225** may receive and store stimulus patterns in stimulus patterns **270** that alter its selection. For example, enhancement stimulus module **225** may receive revised or new stimulus patterns via communication module **230**, such as where updates are required or would be beneficial. For example, if any characteristics of vehicle **100** are physically modified or adjusted by software updates, an update of stimulus patterns for vehicle **100** may be received by enhancement stimulus module **225** and stored in stimulus patterns **270**.

[0059] In some embodiments, enhancement stimulus module **225** may receive an external instruction constraining its selection of a stimulus pattern. For example, an external instruction may be received from another source, such as infrastructure monitoring vehicle **100** or road, via communications module **230**. In some embodiments, an external instruction may specify the stimulus pattern to be used. In some embodiments, external instructions may contain information (e.g., the type of enhancement stimulus required, the occupants to be affected by the stimulus) that acts to limit the stimulus pattern that may be selected by enhancement stimulus module **225**.

[0060] At **430**, enhancement stimulus module **225** may execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold. For example, enhancement stimulus module **225** may execute the massage-based stimulus to affect the driver only when a disengagement likelihood associated with a potential disengagement is between 0.5 and 0.7. As a further example, a first pre-determined threshold may be set at a value substantially lower than where a disengagement warning is given to an operator, while the second pre-determined threshold may be set at or slightly below the value at which a disengagement warning is given.

[0061] Moreover, in some embodiments, enhancement stimulus module **225** may execute the stimulus pattern without regard to any measure of operator vigilance, an estimated mental state of the operator, or any estimation of a physical or mental condition regarding an operator or any occupant of a vehicle. For example, information received from user interfaces involving vehicle systems **140**, in which such information describes user-implemented changes that affect the operation of one or more enhancement stimuli, may constitute a response demonstrating an adverse reaction. For example, turning off a vehicle function or adjusting a vehicle function affected by a stimulus pattern may constitute an adverse reaction.

[0062] In some embodiments, a stimulus pattern may contain restriction conditions that prevent enhancement stimulus module **225** from executing a stimulus pattern. For example, a stimulus pattern may have a restriction condition that prohibits its use during certain weather conditions, within or outside geographic areas, within or outside a range of vehicle speeds, and so on. If enhancement stimulus module **225** determines that the restriction condition is satisfied, then enhancement stimulus module **225** may not execute the stimulus pattern. In some embodiments, an override instruction may be sent to enhancement stimulus module **225** to ignore a restriction condition (e.g., in an emergency situation). In some embodiments, the execution of a stimulus pattern may have no effect on the position of vehicle controls or interfaces relative to that which would have occurred if the stimulus pattern had not been executed.

[0063] At **440**, enhancement stimulus module **225** may terminate the stimulus pattern if an adverse reaction is detected. For example, enhancement stimulus module **225** may terminate a stimulus pattern due to an adverse event associated with the execution of the stimulus pattern as determined by detection module **220**. As another example, enhancement stimulus module **225** may terminate the stimulus pattern because a disengagement warning or takeover request is required. In some embodiments, enhancement stimulus module **225** may terminate a stimulus pattern because enhancement stimulus module **225** determines that a restriction condition has been satisfied by a new change in circumstances of vehicle **100** or its occupants.

[0064] Additional aspects of a method for using stimulus patterns to enhance operator vigilance will be discussed in relation to FIG. **5**. FIG. **5** illustrates a flowchart of a method **500** that is associated with detecting potential disengagement events or potential adverse events. Method **500** will be discussed from the perspective of the vigilance enhancement system **170** of FIGS. **1** and **2**. While method **500** is discussed in combination with the vigilance enhancement system **170** it should be appreciated that the method **500** is not limited to being implemented within the vigilance enhancement system **170** but is instead one example of a system that may implement the method **500**.

[0065] At **510**, the detection module **220** may control the sensor system **120** to acquire the sensor data **250**. In one embodiment, the detection module **220** controls the radar sensor **123** and the camera **126** of the vehicle **100** to observe the surrounding environment. As part of controlling the sensors to acquire the sensor data **250**, it is generally understood that the sensors acquire the sensor data **250** of a

region around the vehicle **100** with data acquired from different types of sensors generally overlapping in order to provide for a comprehensive sampling of the surrounding environment at each time step. In general, the sensor data **250** need not be of the exact same bounded region in the surrounding environment but should include a sufficient area of overlap such that distinct aspects of the area can be correlated. Thus, the detection module **220**, in one embodiment, controls the sensors to acquire the sensor data **250** of the surrounding environment, which may contain disengagement-risk data.

[0066] In some embodiments, the detection module **220** may control the sensor system **120** to acquire the sensor data **250** so as to allow for detection of adverse events. In one embodiment, the detection module **220** controls the vehicle sensor(s) **121**, the camera **126**, and information from user interfaces of vehicle systems **140** to observe the environment of the vehicle occupants. For example, detection module **220** may rely on grip sensors, force sensors, capacitive sensors, EEG, gaze or gesture tracking, control inputs, weight sensors, microphones, or any other measurements that allow for detection of adverse events.

[0067] At **520**, detection module **220** in some embodiments may receive disengagement-risk data relating to potential or actual disengagements from other vehicles or sources (e.g., a disengagement tracking database associated with a geographic area). Such disengagement-risk data may include any information relating to an increased likelihood of a disengagement or the cause of an actual disengagement, including but not limited to vehicle parameters, vehicle environment information, extrinsic data (e.g., weather, emergency data, traffic data), and so on. In some embodiments, disengagement-risk data may only be collected if the associated likelihood of potential disengagement is above a pre-determined threshold. In further embodiments, the pre-determined threshold may be adjusted relative to the context of a potential disengagement (e.g., a lower threshold for higher-risk environments such as intersections, school zones, or unusual adverse weather conditions). In some embodiments, the disengagement-risk data may be stored in sensor data **250**.

[0068] Moreover, in further embodiments, the detection module **220** controls the sensors to acquire the sensor data **250** at successive iterations or time steps. Thus, the detection module **220**, in one embodiment, iteratively executes the functions described at **510** and **520** to acquire the sensor data **250**, including any disengagement-risk data, and provide information therefrom. Furthermore, the detection module **220**, in one embodiment, executes one or more of the noted functions in parallel for separate observations in order to maintain updated perceptions. Additionally, as previously noted, the detection module **220**, when acquiring data from multiple sensors, fuses the data together to form the sensor data **250** and to provide for improved determinations of detection, location, and so on.

[0069] At **530**, the detection module **220** may evaluate the disengagement-risk data or sensor data **250** as a whole to determine a potential disengagement event that may occur for vehicle **100**. For example, based on similarities or dissimilarities with an event in the disengagement-risk data, detection module **220** may determine that a potential disengagement event exists. For example, if a vehicle previously in similar circumstances to vehicle **100** determined a risk of potential disengagement or encountered an actual disengagement, detection module **220** may determine that a potential disengagement event exists.

[0070] For each potential disengagement event determined by detection module **220**, detection module **220** may also determine a likelihood of disengagement associated with the potential disengagement event. For example, detection module **220** may determine on approaching an intersection that a first potential disengagement event with a probability of 0.5 exists and that immediately after the intersection a second potential disengagement event on a highway on-ramp with a probability of 0.3 exists.

[0071] At **540**, the detection module **220** may determine if an adverse reaction by a vehicle occupant has occurred. An adverse reaction may include any detectable action by an occupant of a vehicle that may be interpreted as a response to an enhancement stimulus. For example, an adverse reaction may include interacting with a steering wheel, an interactive screen, gas or brake pedals, seat controls, dashboard controls, or any other vehicle user interface that may be interpreted as indicating a user response to an enhancement stimulus. In some embodiments, a response may only be designated as an adverse reaction if it satisfies criteria established for an enhancement stimulus. For example, a massage stimulus pattern may limit adverse reactions to responses by a vehicle occupant that only affects the massage system. In addition, time constraints may be employed in some embodiments to determine whether a response is an adverse reaction. For example, a response may need to occur within a time frame after a change is made to an enhancement stimulus (e.g., a change in intensity or frequency). In some embodiments, detection module **220** may determine that a response is not an adverse reaction due to an intervening notification or warning to an occupant (e.g., disengagement warning, takeover request, text message, phone call, low battery warning). In some embodiments, detection module **220** may determine that a response is not an adverse reaction due to changes in the environment surrounding the vehicle (e.g., horn honk, headlight flash, tire squeal, rain). In some embodiments, detection module **220** may determine that a response is not an adverse reaction due to action undertaken by another occupant (e.g., changing radio volume, lowering a window, speaking to, or touching another occupant).

[0072] At **550**, detection module **220** may evaluate an adverse reaction in terms of active enhancement stimuli and enter a user engagement event record in user engagement event data **260**. As shown in FIG. **6**, a user engagement event record stored within user engagement event data **260** may contain information relating to the type of adverse reaction, the intensity of the adverse reaction, the occupant responsible for the adverse reaction, the enhancement stimuli in effect when the adverse reaction was detected (e.g., based on vehicle systems being affected by stimulus patterns executed by enhancement stimulus module **225**), any positive association determined between the adverse reaction and an enhancement stimulus, any negative association determined between the adverse reaction and an enhancement stimulus, and any restriction conditions in effect on an enhancement stimulus in operation.

[0073] In determining whether an enhancement stimulus has a positive or negative association with an adverse reaction, detection module **220** may evaluate the adverse reaction with respect to any changes in intensity, frequency, or other characteristics of the enhancement stimulus. For

example, an enhancement stimulus may have a higher positive association the more recently a change with regard to the stimulus occurred before the occurrence of the adverse reaction. In addition, any enhancement stimulus that did not change after a pre-determined threshold prior to the adverse reaction may be accorded a negative association, the value of which may increase the further in past such a change occurred relative to the pre-determined threshold. In some embodiments, the type and intensity of the adverse reaction may be evaluated in order to determine the magnitude of a positive or negative association with an adverse reaction. For example, an adverse reaction involving massage controls may be more positively associated with a massage stimulus, while negatively associated with a temperature-based stimulus. As another example, the intensity with which an occupant engages the steering wheel or pedal inputs in an adverse reaction to a seat position/incline-based enhancement stimulus may determine the magnitude of the positive association of the adverse reaction to the seat position/incline-based enhancement stimulus.

[0074] At **560**, detection module **220** may analyze user engagement event data **260** to determine adjustments to be made to an enhancement stimulus. For example, if user engagement event data **260** indicates strong or frequent positive associations with adverse events to a massage-based enhancement stimulus, detection module **220** may accordingly adjust the characteristics of the stimulus pattern being used or set a restriction condition within the stimulus pattern. For example, detection module **220** may instruct that a stimulus pattern in stimulus patterns **270** be scaled down in terms of magnitude, adjusted in terms of frequency or scaled down with respect to other characteristics. In some embodiments, such a process may repeat until the frequency or intensity of positive associations of an enhancement stimulus with respect to adverse events satisfies a pre-determined threshold. In some embodiments, detection module **220** may alternatively scale up a stimulus pattern in terms of magnitude or other characteristics if the frequency or intensity of positive associations of an enhancement stimulus with respect to adverse events is well below a pre-determined threshold. In further embodiments, such scaling up may only occur for a stimulus pattern if the frequency or intensity of negative associations with respect to adverse events is above a pre-determined threshold. In some embodiments, detection module **220** may set a restriction condition that prohibits the operation of a stimulus pattern, such as where scaling or other adjustments to a stimulus pattern does not adequately reduce the frequency or intensity of positive associations of the stimulus pattern with respect to adverse reactions (e.g., below a pre-determined threshold).

[0075] Additional aspects of a method for using stimulus patterns to enhance operator vigilance will be discussed in relation to FIG. **7**. FIG. **7** illustrates a flowchart of a method **700** that is associated with targeting a stimulus pattern with respect to an enhancement stimulus. Method **700** will be discussed from the perspective of the vigilance enhancement system **170** of FIGS. **1** and **2**. While method **700** is discussed in combination with the vigilance enhancement system **170** it should be appreciated that the method **700** is not limited to being implemented within the vigilance enhancement system **170** but is instead one example of a system that may implement the method **700**.

[0076] At **710**, enhancement stimulus module **225** may select a target location. For example, enhancement stimulus module **225** may select an area associated with a driver's seat, a front passenger seat, or a rear passenger seat. In some embodiments, the occupant may be selected (e.g., driver, front passenger) as a proxy for a target location.

[0077] At **720**, enhancement stimulus module **225** may adjust one or more stimulus patterns such that the combined effect of the one or more stimulus patterns are estimated to have a maximum impact at the target location. In adjusting the one or more stimulus patterns, enhancement stimulus module **225** may take into account information regarding characteristics of the vehicle that may affect an estimate of maximum impact.

[0078] At **730**, enhancement stimulus module **225** may execute the stimulus patterns to target the location. In some embodiments, enhancement stimulus module **225** may further adjust the one or more stimulus patterns based on sensor data **250** to obtain a better estimate of where the maximum impact of the stimulus patterns is occurring.

[0079] At **740**, enhancement stimulus module **225** may select a new target location if after a pre-determined amount of time the targeted stimulus is determined to have an insufficient effect on an occupant.

[0080] FIG. **1** will now be discussed in full detail as an example environment within which the system and methods disclosed herein may operate. In some instances, the vehicle **100** is configured to switch selectively between an autonomous mode, one or more semi-autonomous operational modes, or a manual mode. Such switching can be implemented in a suitable manner, now known, or later developed. "Manual mode" means that all of or a majority of the navigation or maneuvering of the vehicle is performed according to inputs received from a user (e.g., human driver). In one or more arrangements, the vehicle **100** can be a conventional vehicle that is configured to operate in only a manual mode.

[0081] In one or more embodiments, the vehicle **100** is an autonomous vehicle. As used herein, "autonomous vehicle" refers to a vehicle that operates in an autonomous mode. "Autonomous mode" refers to navigating or maneuvering the vehicle **100** along a travel route using one or more computing systems to control the vehicle **100** with minimal or no input from a human driver. In one or more embodiments, the vehicle **100** is highly automated or completely automated. In one embodiment, the vehicle **100** is configured with one or more semi-autonomous operational modes in which one or more computing systems perform a portion of the navigation or maneuvering of the vehicle along a travel route, and a vehicle operator (i.e., driver) provides inputs to the vehicle to perform a portion of the navigation or maneuvering of the vehicle **100** along a travel route.

[0082] The vehicle **100** can include one or more processors **110**. In one or more arrangements, the processor(s) **110** can be a main processor of the vehicle **100**. For instance, the processor(s) **110** can be an electronic control unit (ECU). The vehicle **100** can include one or more data stores **115** for storing one or more types of data. The data store **115** can include volatile or non-volatile memory. Examples of suitable data stores **115** include RAM (Random Access Memory), flash memory, ROM (Read Only Memory), PROM (Programmable Read-Only Memory), EPROM (Erasable Programmable Read-Only Memory), EEPROM (Electrically Erasable Programmable Read-Only Memory),

registers, magnetic disks, optical disks, hard drives, or any other suitable storage medium, or any combination thereof. The data store **115** can be a component of the processor(s) **110**, or the data store **115** can be operatively connected to the processor(s) **110** for use thereby. The term "operatively connected," as used throughout this description, can include direct or indirect connections, including connections without direct physical contact.

[0083] In one or more arrangements, the one or more data stores **115** can include map data **116**. The map data **116** can include maps of one or more geographic areas. In some instances, the map data **116** can include information or data on roads, traffic control devices, road markings, structures, features, or landmarks in the one or more geographic areas. The map data **116** can be in any suitable form. In some instances, the map data **116** can include aerial views of an area. In some instances, the map data **116** can include ground views of an area, including 360-degree ground views. The map data **116** can include measurements, dimensions, distances, or information for one or more items included in the map data **116** or relative to other items included in the map data **116**. The map data **116** can include a digital map with information about road geometry. The map data **116** can be high quality or highly detailed.

[0084] In one or more arrangements, the map data **116** can include one or more terrain maps **117**. The terrain map(s) **117** can include information about the ground, terrain, roads, surfaces, or other features of one or more geographic areas. The terrain map(s) **117** can include elevation data in the one or more geographic areas. The map data **116** can be high quality or highly detailed. The terrain map(s) **117** can define one or more ground surfaces, which can include paved roads, unpaved roads, land, and other things that define a ground surface.

[0085] In one or more arrangements, the map data **116** can include one or more static obstacle maps **118**. The static obstacle map(s) **118** can include information about one or more static obstacles located within one or more geographic areas. A "static obstacle" is a physical object whose position does not change or substantially change over a period of time or whose size does not change or substantially change over a period of time. Examples of static obstacles include trees, buildings, curbs, fences, railings, medians, utility poles, statues, monuments, signs, benches, furniture, mailboxes, large rocks, hills. The static obstacles can be objects that extend above ground level. The one or more static obstacles included in the static obstacle map(s) **118** can have location data, size data, dimension data, material data, or other data associated with it. The static obstacle map(s) **118** can include measurements, dimensions, distances, or information for one or more static obstacles. The static obstacle map(s) **118** can be high quality or highly detailed. The static obstacle map(s) **118** can be updated to reflect changes within a mapped area.

[0086] The one or more data stores **115** can include sensor data **119**. In this context, "sensor data" means any information about the sensors that the vehicle **100** is equipped with, including the capabilities and other information about such sensors. As will be explained below, the vehicle **100** can include the sensor system **120**. The sensor data **119** can relate to one or more sensors of the sensor system **120**. As an example, in one or more arrangements, the sensor data **119** can include information on one or more LIDAR sensors **124** of the sensor system **120**.

[0087] In some instances, at least a portion of the map data **116** or the sensor data **119** can be located in one or more data stores **115** located onboard the vehicle **100**. Alternatively, or in addition, at least a portion of the map data **116** or the sensor data **119** can be located in one or more data stores **115** that are located remotely from the vehicle **100**.

[0088] As noted above, the vehicle **100** can include the sensor system **120**. The sensor system **120** can include one or more sensors. "Sensor" means any device, component or system that can detect, or sense something. The one or more sensors can be configured to detect, or sense in real-time. As used herein, the term "real-time" means a level of processing responsiveness that a user or system senses as sufficiently immediate for a particular process or determination to be made, or that enables the processor to keep up with some external process.

[0089] In arrangements in which the sensor system **120** includes a plurality of sensors, the sensors can work independently from each other. Alternatively, two or more of the sensors can work in combination with each other. In such case, the two or more sensors can form a sensor network. The sensor system **120** or the one or more sensors can be operatively connected to the processor(s) **110**, the data store(s) **115**, or another element of the vehicle **100** (including any of the elements shown in FIG. **1**). The sensor system **120** can acquire data of at least a portion of the external environment of the vehicle **100** (e.g., nearby vehicles).

[0090] The sensor system **120** can include any suitable type of sensor. Various examples of different types of sensors will be described herein. However, it will be understood that the embodiments are not limited to the particular sensors described. The sensor system **120** can include one or more vehicle sensors **121**. The vehicle sensor(s) **121** can detect, determine, or sense information about the vehicle **100** itself. In one or more arrangements, the vehicle sensor(s) **121** can be configured to detect, or sense position and orientation changes of the vehicle **100**, such as, for example, based on inertial acceleration. In one or more arrangements, the vehicle sensor(s) **121** can include one or more accelerometers, one or more gyroscopes, an inertial measurement unit (IMU), a dead-reckoning system, a global navigation satellite system (GNSS), a global positioning system (GPS), a navigation system **147**, and/or other suitable sensors. The vehicle sensor(s) **121** can be configured to detect, or sense one or more characteristics of the vehicle **100**. In one or more arrangements, the vehicle sensor(s) **121** can include a speedometer to determine a current speed of the vehicle **100**.

[0091] Alternatively, or in addition, the sensor system **120** can include one or more environment sensors **122** configured to acquire, or sense driving environment data. "Driving environment data" includes data or information about the external environment in which an autonomous vehicle is located or one or more portions thereof. For example, the one or more environment sensors **122** can be configured to detect, quantify, or sense obstacles in at least a portion of the external environment of the vehicle **100** or information/data about such obstacles. Such obstacles may be stationary objects or dynamic objects. The one or more environment sensors **122** can be configured to detect, measure, quantify or sense other things in the external environment of the vehicle **100**, such as, for example, lane markers, signs, traffic lights, traffic signs, lane lines, crosswalks, curbs proximate the vehicle **100**, off-road objects, etc.

[0092] Various examples of sensors of the sensor system **120** will be described herein. The example sensors may be part of the one or more environment sensors **122** or the one or more vehicle sensors **121**. However, it will be understood that the embodiments are not limited to the particular sensors described.

[0093] As an example, in one or more arrangements, the sensor system **120** can include one or more radar sensors **123**, one or more LIDAR sensors **124**, one or more sonar sensors **125**, or one or more cameras **126**. In one or more arrangements, the one or more cameras **126** can be high dynamic range (HDR) cameras or infrared (IR) cameras.

[0094] The vehicle **100** can include an input system **130**. An "input system" includes any device, component, system, element or arrangement or groups thereof that enable information/data to be entered into a machine. The input system **130** can receive an input from a vehicle passenger (e.g., a driver or a passenger). The vehicle **100** can include an output system **135**. An "output system" includes any device, component, or arrangement or groups thereof that enable information/data to be presented to a vehicle passenger (e.g., a person, a vehicle passenger, etc.).

[0095] The vehicle **100** can include one or more vehicle systems **140**. Various examples of the one or more vehicle systems **140** are shown in FIG. **1**. However, the vehicle **100** can include more, fewer, or different vehicle systems. It should be appreciated that although particular vehicle systems are separately defined, each or any of the systems or portions thereof may be otherwise combined or segregated via hardware or software within the vehicle **100**. The vehicle **100** can include a propulsion system **141**, a braking system **142**, a steering system **143**, throttle system **144**, a transmission system **145**, a signaling system **146**, or a navigation system **147**. Each of these systems can include one or more devices, components, or a combination thereof, now known or later developed.

[0096] The navigation system **147** can include one or more devices, applications, or combinations thereof, now known or later developed, configured to determine the geographic location of the vehicle **100** or to determine a travel route for the vehicle **100**. The navigation system **147** can include one or more mapping applications to determine a travel route for the vehicle **100**. The navigation system **147** can include a global positioning system, a local positioning system or a geolocation system.

[0097] The processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** can be operatively connected to communicate with the various vehicle systems **140** or individual components thereof. For example, returning to FIG. **1**, the processor(s) **110** or the automated driving module(s) **160** can be in communication to send or receive information from the various vehicle systems **140** to control the movement, speed, maneuvering, heading, direction, etc. of the vehicle **100**. The processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** may control some or all of these vehicle systems **140** and, thus, may be partially or fully autonomous.

[0098] The processor(s) **110**, vigilance enhancement system **170**, or the automated driving module(s) **160** can be operatively connected to communicate with the various vehicle systems **140** or individual components thereof. For example, returning to FIG. **1**, the processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** can be in communication to send or receive information from the various vehicle systems **140** to control the movement, speed, maneuvering, heading, direction, etc. of the vehicle **100**. The processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** may control some or all of these vehicle systems **140**.

[0099] The processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** may be operable to control the navigation or maneuvering of the vehicle **100** by controlling one or more of the vehicle systems **140** or components thereof. For instance, when operating in an autonomous mode, the processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** can control the direction or speed of the vehicle **100**. The processor(s) **110**, the vigilance enhancement system **170**, or the automated driving module(s) **160** can cause the vehicle **100** to accelerate (e.g., by increasing the supply of fuel provided to the engine), decelerate (e.g., by decreasing the supply of fuel to the engine or by applying brakes) or change direction (e.g., by turning the front two wheels). As used herein, "cause" or "causing" means to make, force, compel, direct, command, instruct, or enable an event or action to occur or at least be in a state where such event or action may occur, either in a direct or indirect manner.

[0100] The vehicle **100** can include one or more actuators **150**. The actuators **150** can be any element or combination of elements operable to modify, adjust or alter one or more of the vehicle systems **140** or components thereof to responsive to receiving signals or other inputs from the processor(s) **110** or the automated driving module(s) **160**. Any suitable actuator can be used. For instance, the one or more actuators **150** can include motors, pneumatic actuators, hydraulic pistons, relays, solenoids, or piezoelectric actuators, just to name a few possibilities.

[0101] The vehicle **100** can include one or more modules, at least some of which are described herein. The modules can be implemented as computer-readable program code that, when executed by a processor **110**, implement one or more of the various processes described herein. One or more of the modules can be a component of the processor(s) **110**, or one or more of the modules can be executed on or distributed among other processing systems to which the processor(s) **110** is operatively connected. The modules can include instructions (e.g., program logic) executable by one or more processor(s) **110**. Alternatively, or in addition, one or more data store **115** may contain such instructions.

[0102] In one or more arrangements, one or more of the modules described herein can include artificial or computational intelligence elements, e.g., neural network, fuzzy logic, or other machine learning algorithms. Further, in one or more arrangements, one or more of the modules can be distributed among a plurality of the modules described herein. In one or more arrangements, two or more of the modules described herein can be combined into a single module.

[0103] The vehicle **100** can include one or more autonomous driving modules **160**. The automated driving module(s) **160** can be configured to receive data from the sensor system **120** or any other type of system capable of capturing information relating to the vehicle **100** or the external environment of the vehicle **100**. In one or more arrangements, the automated driving module(s) **160** can use such data to generate one or more driving scene models. The

automated driving module(s) **160** can determine position and velocity of the vehicle **100**. The automated driving module(s) **160** can determine the location of obstacles, obstacles, or other environmental features including traffic signs, trees, shrubs, neighboring vehicles, pedestrians, etc.

[0104] The automated driving module(s) **160** can be configured to receive, or determine location information for obstacles within the external environment of the vehicle **100** for use by the processor(s) **110**, or one or more of the modules described herein to estimate position and orientation of the vehicle **100**, vehicle position in global coordinates based on signals from a plurality of satellites, or any other data or signals that could be used to determine the current state of the vehicle **100** or determine the position of the vehicle **100** with respect to its environment for use in either creating a map or determining the position of the vehicle **100** in respect to map data.

[0105] The automated driving module(s) **160** either independently or in combination with the vigilance enhancement system **170** can be configured to determine travel path(s), current autonomous driving maneuvers for the vehicle **100**, future autonomous driving maneuvers or modifications to current autonomous driving maneuvers based on data acquired by the sensor system **120**, driving scene models, or data from any other suitable source such as determinations from the sensor data **250**. In general, the automated driving module(s) **160** may function to implement different levels of automation, including advanced driving assistance (ADAS) functions, semi-autonomous functions, and fully autonomous functions. "Driving maneuver" means one or more actions that affect the movement of a vehicle. Examples of driving maneuvers include accelerating, decelerating, braking, turning, moving in a lateral direction of the vehicle **100**, changing travel lanes, merging into a travel lane, or reversing, just to name a few possibilities. The automated driving module(s) **160** can be configured can be configured to implement determined driving maneuvers. The automated driving module(s) **160** can cause, directly or indirectly, such autonomous driving maneuvers to be implemented. As used herein, "cause" or "causing" means to make, command, instruct, or enable an event or action to occur or at least be in a state where such event or action may occur, either in a direct or indirect manner. The automated driving module(s) **160** can be configured to execute various vehicle functions or to transmit data to, receive data from, interact with, or control the vehicle **100** or one or more systems thereof (e.g., one or more of vehicle systems **140**).

[0106] Detailed embodiments are disclosed herein. However, it is to be understood that the disclosed embodiments are intended only as examples. Therefore, specific structural and functional details disclosed herein are not to be interpreted as limiting, but merely as a basis for the claims and as a representative basis for teaching one skilled in the art to variously employ the aspects herein in virtually any appropriately detailed structure. Further, the terms and phrases used herein are not intended to be limiting but rather to provide an understandable description of possible implementations. Various embodiments are shown in FIGS. **1-7**, but the embodiments are not limited to the illustrated structure or application.

[0107] The flowcharts and block diagrams in the figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer program products according to various embodiments. In this regard, each block in the flowcharts or block diagrams may represent a module, segment, or portion of code, which comprises one or more executable instructions for implementing the specified logical function(s). It should also be noted that, in some alternative implementations, the functions noted in the block may occur out of the order noted in the figures. For example, two blocks shown in succession may, in fact, be executed substantially concurrently, or the blocks may sometimes be executed in the reverse order, depending upon the functionality involved.

[0108] The systems, components or processes described above can be realized in hardware or a combination of hardware and software and can be realized in a centralized fashion in one processing system or in a distributed fashion where different elements are spread across several interconnected processing systems. Any kind of processing system or another apparatus adapted for carrying out the methods described herein is suited. A typical combination of hardware and software can be a processing system with computer-usable program code that, when being loaded and executed, controls the processing system such that it carries out the methods described herein. The systems, components or processes also can be embedded in a computer-readable storage, such as a computer program product or other data programs storage device, readable by a machine, tangibly embodying a program of instructions executable by the machine to perform methods and processes described herein. These elements also can be embedded in an application product which comprises all the features enabling the implementation of the methods described herein and, which when loaded in a processing system, is able to carry out these methods.

[0109] Furthermore, arrangements described herein may take the form of a computer program product embodied in one or more computer-readable media having computer-readable program code embodied, e.g., stored, thereon. Any combination of one or more computer-readable media may be utilized. The computer-readable medium may be a computer-readable signal medium or a computer-readable storage medium. The phrase "computer-readable storage medium" means a non-transitory storage medium. A computer-readable storage medium may be, for example, but not limited to, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples (a non-exhaustive list) of the computer-readable storage medium would include the following: a portable computer diskette, a hard disk drive (HDD), a solid-state drive (SSD), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), a digital versatile disc (DVD), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing. In the context of this document, a computer-readable storage medium may be any tangible medium that can contain or store a program for use by or in connection with an instruction execution system, apparatus, or device.

[0110] Generally, modules as used herein include routines, programs, objects, components, data structures, and so on that perform particular tasks or implement particular data types. In further aspects, a memory generally stores the noted modules. The memory associated with a module may be a buffer or cache embedded within a processor, a RAM,

a ROM, a flash memory, or another suitable electronic storage medium. In still further aspects, a module as envisioned by the present disclosure is implemented as an application-specific integrated circuit (ASIC), a hardware component of a system on a chip (SoC), as a programmable logic array (PLA), or as another suitable hardware component that is embedded with a defined configuration set (e.g., instructions) for performing the disclosed functions.

[0111] Program code embodied on a computer-readable medium may be transmitted using any appropriate medium, including but not limited to wireless, wireline, optical fiber, cable, RF, etc., or any suitable combination of the foregoing. Computer program code for carrying out operations for aspects of the present arrangements may be written in any combination of one or more programming languages, including an object-oriented programming language such as Java™ Smalltalk, C++, or the like and conventional procedural programming languages, such as the "C" programming language or similar programming languages. The program code may execute entirely on the user's computer, partly on the user's computer, as a stand-alone software package, partly on the user's computer and partly on a remote computer, or entirely on the remote computer or server. In the latter scenario, the remote computer may be connected to the user's computer through any type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made to an external computer (for example, through the Internet using an Internet Service Provider).

[0112] The terms "a" and "an," as used herein, are defined as one or more than one. The term "plurality," as used herein, is defined as two or more than two. The term "another," as used herein, is defined as at least a second or more. The terms "including" or "having," as used herein, are defined as comprising (i.e., open language). The phrase "at least one of . . . and . . . " as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items. As an example, the phrase "at least one of A, B, and C" includes A only, B only, C only, or any combination thereof (e.g., AB, AC, BC, or ABC).

[0113] Aspects herein can be embodied in other forms without departing from the spirit or essential attributes thereof. Accordingly, reference should be made to the following claims, rather than to the foregoing specification, as indicating the scope hereof.

What is claimed is:

1. A system for a vehicle, comprising:

a processor; and a memory storing machine-readable instructions that, when executed by the processor, cause the processor to:

receive a disengagement likelihood;

select a stimulus pattern that if executed adjusts a vehicle function; and

execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

2. The system of claim **1**, wherein the machine-readable instructions further includes an instruction that, when executed by the processor, cause the processor to:

alter how the stimulus pattern adjusts the vehicle function if the disengagement likelihood changes.

3. The system of claim **2**, wherein the second threshold is at or below a disengagement notification threshold.

4. The system of claim **3**, wherein the machine-readable instructions further includes an instruction that, when executed by the processor, cause the processor to:

prohibit the execution of the stimulus pattern if a restriction condition exists.

5. The system of claim **4**, wherein the machine-readable instructions further includes an instruction that, when executed by the processor, cause the processor to:

terminate the execution of the stimulus pattern if an adverse reaction is detected.

6. The system of claim **5**, wherein the adverse reaction is detected only if a response satisfies a relationship condition specified in the stimulus pattern.

7. The system of claim **6**, wherein the machine-readable instructions further includes an instruction that, when executed by the processor, cause the processor to:

alter how the stimulus pattern adjusts the vehicle function based on positive or negative associations with one or more adverse reactions.

8. The system of claim **1**, wherein the machine-readable instructions to select or execute the stimulus pattern occurs regardless of any estimates of an operator vigilance.

9. A non-transitory computer-readable medium including instructions that when executed by one or more processors cause the one or more processors to:

receive a disengagement likelihood;

select a stimulus pattern that if executed adjusts a vehicle function; and

execute the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

10. The non-transitory computer-readable medium of claim **9**, wherein the instructions to execute the stimulus pattern further includes to alter how the stimulus pattern adjusts the vehicle function if the disengagement likelihood changes.

11. The non-transitory computer-readable medium of claim **10**, wherein the second threshold is at or below a disengagement notification threshold.

12. The non-transitory computer-readable medium of claim **11**, wherein the instructions to execute the stimulus pattern include instructions prohibiting the execution of the stimulus pattern if a restriction condition exists.

13. The non-transitory computer-readable medium of claim **12**, wherein the medium further includes an instruction that when executed by one or more processors causes the one or more processors to terminate the execution of the stimulus pattern if an adverse reaction is detected.

14. A method for enhancing operator vigilance, the method comprising:

receiving a disengagement likelihood;

selecting a stimulus pattern that if executed adjusts a vehicle function; and

executing the stimulus pattern if the disengagement likelihood is above a first threshold and below a second threshold.

15. The method of claim **14**, wherein executing the stimulus pattern includes altering how the stimulus pattern adjusts the vehicle function if the disengagement likelihood changes.

16. The method of claim **15**, wherein the second threshold is at or below a disengagement notification threshold.

17. The method of claim **16**, wherein executing the stimulus pattern includes prohibiting the execution of the stimulus pattern if a restriction condition exists.

18. The method of claim **17**, further comprising:

terminating the stimulus pattern if an adverse reaction is detected.

19. The method of claim **18**, wherein the adverse reaction is detected only if a response satisfies a relationship condition specified in the stimulus pattern.

20. The method of claim **19**, further comprising:

altering how the stimulus pattern adjusts the vehicle function based on positive or negative associations with one or more adverse reactions.

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