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An Approach to Design Variables for Analysis of Conditionally Automated Driving Transitions

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ABSTRACT

In conditionally automated vehicles, drivers can occasionally activate the autopilot to perform driving tasks such as steering and braking. During this time, the driver may participate in secondary tasks such as reading and monitoring the surrounding. However, the driver must stay alert to a potential request to resume driving in situations that cannot be managed by the autopilot. The situation awareness of drivers in such driving situations that cannot be managed by the autopilot is required to avoid accidents during the transition. Previous studies indicate that various variables such as complexity of surrounding traffic conditions, secondary tasks, speed of subject vehicle, and previous takeover transition experience affect takeover performance. However, the approach to utilize these variables to enable efficient takeover transitions have not been determined. This contribution discusses a systematic design of these variables. It utilizes known dimensions of complex dynamical systems and fundamentals of human cognitive processes to design driving scenarios and secondary tasks. The characteristics of the variables are systemically varied to generate different driving situations to better understand how they determine takeover transitions and interaction.

1. INTRODUCTION

Despite innovations in intelligent driver assistance systems in the last decade, problems related to safety and reliability persist. More features such as lane changing and lane keeping assistance systems have considerably improved safety and reduced accidents, but the intended safety goals have not been completely achieved. A framework defined by the (Society of Automotive Engineers, 2018) includes six levels of driving automation ranging from 0 to 5 by which automated vehicles are classified. Level 0 represents no automation, where the driver is fully in control of all aspects of driving. Level 1 introduces driver assistance features like adaptive cruise control or lane keeping assist, but the driver must remain attentive and in control of the vehicle. Level 2 allows for partial automation, where the autopilot can control both steering and acceleration/deceleration simultaneously, but the driver must still be ready to take over control at any time. Level 3 enables conditional automation, where the autopilot can handle all aspects of driving under certain conditions, but the driver must be ready to respond and resume driving when the system requests. Level 4 achieves high automation, where the autopilot can operate without human intervention in specific environments but may still have limitations. Finally, Level 5 represents full automation, where the vehicle

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can drive itself in all conditions without any human input. Most research efforts including this contribution are presently focused on level 3 (termed "conditional driving automation") and higher levels.

In Level 3 automation, the automated driving system (ADS) performs the entire dynamic (lateral and longitudinal) driving task (DDT) until the system limits are reached. At this point, the fallback ready driver should be receptive to a request to intervene (RTI) from the ADS and resume performance of the DDT within a few seconds. The process between the RTI and when the driver resumes, or takeover driving is referred to as a takeover transition in this contribution.

In the study of RTI, many factors and variables that affect driver decisions and actions must be considered. Among them is situation awareness (SA) which is the "human perception of elements of current situation using the senses, comprehension of their meaning, and projection of their status in the near future" (Endsley, 1988). In other words, the level of driver situation awareness and subsequent quality of manoeuvre are required for safety and avoidance of accidents.

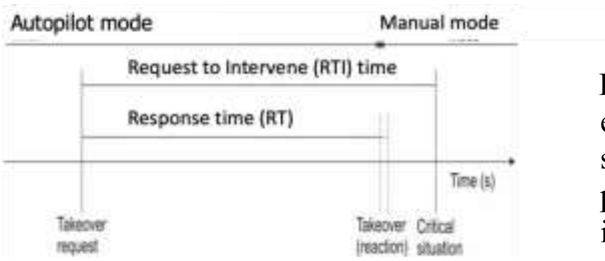

Fig. 1. RTI timeline

Two variables that are critical to safety focused on in this contribution are response time (RT) and RTI time as distinguished in Fig. 1. Response time is the time between RTI and driver reaction (Hergeth et al., 2017). While RTI time is the time between RTI and when subject vehicle is expected to reach critical situation (Kim and Yang, 2017), (Wang and Söffker, 2018). Other variables include secondary tasks (STs) and driving environment variables, and related complexity. Secondary tasks are tasks that the driver can perform while the vehicle is in autopilot e.g., reading an e-mail (Braunagel et al., 2017). Driving environment variables may include speed of the subject, traffic density, number of lanes etc.

Various studies have been conducted on takeover transitions which indicate that the response time for different drivers in different situations vary strongly.

This indicates that response time is interdependent on certain variables such as RTI (e.g., RTI time limits the time frame for driver reaction). This contribution focuses on the requirements for designing these interdependent variables to enable analysis of takeover transitions which will ensure optimal and timely reaction of drivers.

The outline of the paper includes a review of related studies and an analysis about the design of RTI variables. These variables include scenarios, critical situations, and secondary tasks. Special consideration is given to the concept of the complexity of situations, their composition, and relation to drivers' situation awareness. Finally, summary and outlook are given.

2. STATE-OF-THE-ART

In the study by (Hergeth et al., 2017), prior experience with takeover transitions was studied to observe its effect on driver takeover performance and automation trust. The study involved four groups of drivers who were given different information content about RTI - (1) no prior experience, (2) description of the RTI process, (3) handson experience with RTI, and (4) description plus RTI experience. The drivers in each group participated in an experiment where they experienced two RTI. The results show that the response time reduced during the second RTI compared to the first for all the groups of drivers. Additional evaluation metrics such as time to collision (TTC) also showed improvement in the second RTI. In the post experiment questionnaire, majority of the participants expressed more trust and confidence in the ADS during the second RTI compared to the first. The study concluded that, driver performance and trust in automation improves with RTI experience. However, the conditions during the two RTIs were identical. The authors concluded that adaptation (also known as learning effect) has influence on the improved performance of drivers in the second RTI.

In another study by (Kühn et al., 2017), the response time of drivers were investigated. Five different takeover scenarios and two secondary tasks (STs) (reading and playing a Tetris game) were tested in a driving simulator with 60 participants. It was observed that 90 % of drivers required more than eight seconds to react correctly. That is, 90 % required 8 s to complete all actions (glance at the road, place hands on steering, place feet on pedal, turn automated system off, glance at mirror, and glance at speedometer) intended to gain awareness of the situation. The study shows the range of reaction times observed across the studied scenarios.

The study, however, did not separate the various behaviours observed nor analyse them in comparison with the different studied scenarios. For example, what influenced the drivers' responses and how can the resulting inference be implemented to stimulate the right responses from drivers?

Another study by (Braunagel et al., 2017) classified drivers' takeover readiness based on features (type of ST, last gaze, number of gazes, traffic situation complexity), applied to a machine learning algorithm. Low takeover readiness was defined as reduced driving environment monitoring and vice versa. Three complexity levels of traffic situation and three levels of STs were integrated in the study. Each ST included two manual demand options - hand-held- or hands-free-device. Whenever a low takeover readiness was detected, the driver vehicle interface provided a warning sign informing the driver to look at the road more often. If driver does not heed the warning, the ST is changed to one of lower complexity. Among the three features, the authors observed that traffic situation complexity has the strongest influence on the prediction of takeover readiness. This study provides insight into driver behaviour by continually classifying driver readiness in three different scenarios in real time. Each scenario has different complexity levels. However, the study only relied on the ability of the driver to make correct deductions about the driving situation without providing decision support information (suggestions) to optimize performance.

Another takeover transition study involving 38 drivers with a combination of three scenarios, two interfaces, and one secondary task was presented in (Wang and Söffker, 2018). The interfaces provided blind spot warning, subject vehicle position relative to surrounding vehicles, traffic signs e.g., speed limit information, present driving lane and lane change availabilty. The RTI in these scenarios were presented 8 s in advance of the critical situation in front of the driver. In this study, it was observed that not all drivers were able to successfully takeover within the allotted 8 s leading to the critical situation. In fact, the average response time during the first critical situation for all drivers was 9 s. In the subsequent critical situations, the response time reduced, and the performance of drivers improved as they gained experience. However, the subsequent response times though where considerably lower than the first, did not consistently decrease but fluctuated with the critical situations. In addition, it was observed that speed of the vehicle and the situation complexity at the time RTI was issued affected quality of driver performance. How these variables affect the response time and how the response time affects these variables are not determined.

In (Nakajima and Tanaka, 2017) active and passive STs were studied in relation to response time and takeover performance. It was observed that when drivers undertake active STs (e.g., playing a game with a handheld device) the take over time increases in comparison to performing passive tasks (e.g., engaging in a conversation). Other metrics such as maximum lateral acceleration showed that takeover performance decreased during active tasks involving motor skills. How can these findings be integrated into the design of conditionally automated vehicles such that drivers can perform different range of tasks during autonomous mode and still takeover successfully within available time is not discussed. Or should drivers be limited to only passive tasks?

More so, in (Kim and Yang, 2017) the response time of 30 drivers using performance-based metrics namely reaction time, maximum acceleration, number of collisions, and average heart rate was studied. The study utilized response times recorded in previous literature and a performance-based approach to determine RTI time. Similar to the results presented in (Wang and Söffker, 2018), the study observed that response time varied for different situations and drivers. The participants admitted that the RTI time obtained with the performance-based method best improves their awareness of the critical situation. However, they stated that a longer RTI time allows them sufficient time to respond correctly. The study reported that this may be due to the performance-based method RTI occurred at a time the participants could clearly see the critical situation. Whereas the longer RTI time occurred too early to sufficiently be aware of the critical situation. Thus, is it possible that within this time range, lies a sliding point (continually changing times) for each situation that should be determined in real time? How can this be determined in real time?

The reviewed studies report variables and features that have been observed to affect takeover behaviour. These variables and features include traffic situation complexity, situation awareness, speed, STs, and RTI time. The studies, however, do not explain the variability in response time with respect to the other variables and vice versa. That is, how do these variables affect each other and takeover performance?

This contribution involves an analysis of RTI-related background which would enable understanding of how to ascertain a suitable RTI time for drivers. Hence a wide range of scenarios have been designed to observe the varying effect of the variables on each other.

3. FUNDAMENTALS OF COMPLEX DYNAMICAL SYSTEMS: IN RELATION TO DRIVING SCENARIOS

In the last three decades, the interaction of human operators with complex dynamical systems has experienced a paradigm change. This means the human operator is not only acting as a (simple-reflex or rule-based) controller but as a knowledge- and experience-guided individual. The cognitive ability of the human defines the performance of the resulting interaction. Special focus is given to systems of complex dynamical behaviour, which cannot be described by pure equations. Most of the complex dynamical systems in this category are real-world scenarios (such as driving scenarios). These scenarios are strongly affected by human decision, planning, and interaction activities.

A complex dynamical system is characterized by six dimensions namely - complexity, connectivity, dynamics, intransparency, polytely, and variability of goal (Dörner, 1989). These properties are recapped in the following paragraphs based on the definitions given by (Dörner, 1987), (Dörner, 1989), (Dörner, 1999) and interpreted in a formal sense in (Söffker, 2004).

Table 1. Dimensions of complex dynamical systems

Dimensions	Environmental variable examples producing characteristic effects in a traffic-vehicle scenario
Complexity	Increasing number of surrounding vehicles and pedestrians increases complexity due to more possible interactions
Connectivity	Various exits or slowing vehicles ahead influence drivers to adjust maneuvers
Dynamics	Varying speed and lane positions of surrounding vehicles changing scenario constellations
Intransparency	Undulating or curved terrain and rainy, sunny, foggy, or snowy weather hiding information about the environment such as the existence of additional vehicles
Polytely	Safety and time conflicts such as pedestrian crossing in front of driver resulting in conflicting goals and solutions, so drivers have to decide under time pressure for alternatives
Openness of goal	Due to changing scenario state, maneuver sequence (e.g. steering, braking, and throttling) required to reach goals (e.g. stay safe, arrive destination) cannot be defined in one step but are subject to continual driver decisions.

Complexity describes the number of agents within the system. The behaviour of these individual agents affects the overall behaviour of the system. In a traffic scenario, the overall visual meaning of a highway scenario with a few vehicles is different from another highway scenario with dense traffic. The former requires fewer decision constraints to consider during manoeuvres compared to the later. As the number of agents (drivers) increases, the complexity of the system (scenario) increases.

Connectivity describes how changes in the behaviour of one agent results in changes in the behaviour of other agents within the system. Traffic scenarios are connective when drivers' interests are affected by others. A sudden breaking action of a lead vehicle due to an obstacle may cause the vehicles behind it to also break suddenly because of the shared safety interest to avoid collision. This can ripple through to several vehicles behind.

The **Dynamics** property describes the ability of a system to change the problem constellation and/or to evolve with time even without any external influences acting on it. This is because the interacting agents are free within the system. In a typical traffic scenario, the vehicles are in continuous motion while constantly changing the constallation of the system. Increasing the degree of freedom of interacting vehicles increases the dynamics of the system.

Intransparency describes the circumstance where the states of some agents are not directly visible. Any effect restricting the drivers' behaviour which cannot be directly seen (from the traffic scenario) will generate (partial) intransparency. This may happen due to non-visibility of vehicles, but also due to sudden changes in the traffic scenario. Increasing the number of invisible agents (vehicles, pedestrians etc.) increases the intransparency of the system.

Polytely is the property of a system which requires human intervention. During intervention, multiple goals or required states of the agents are possible. The goals could contradict. The fulfilment of one goal automatically induces the non-fulfilment of others. In this case, a traffic scenario involving human drivers is polytelitic, when the driver runs into conflicts due to prioritization of goals. An example is a conflicting situation in which a turning manoeuvre is required but may not be possible without collisions with other traffic participants. Here, the goals 'drive safely' and 'reach the destination' and 'reach the destination in time' are in conflict with one another.

Variability of the goal situation means that the goals to be achieved by an operator's intervention are approximately and not completely accomplishable. That is, a human driver's task to reach a destination in time is variable with respect to the goal situation if the destination is not defined in detail, such that the subtask of the trajectory to drive at each time is not discrete. Furthermore, requirements for 'safe driving' are always variable because it is usually relative.

Table 1 outlines the characteristics of complex dynamical systems and some examples of environment variables that can produce the related effects in a driving scenario. That is for example, sudden appearance of fog can result in intransparency because an obstacle such as a stopped vehicle may lie within. These environmental variables are integrated in the designed scenarios to generate the associated effect as discussed in the subsequent sections.

3.1 Scenarios and RTI-related critical situations

To design driving scenarios the different dimensions of complex dynamical systems must be considered and suitably modified. In this study, a driving scenario refers to the sum of events within each driving route. As previously mentioned, there are driving environmental variables that produce the effects of the different dimensions of complex dynamical systems. These may include: the position and relative speed of vehicles, possible driving actions such as steering and breaking, type of road terrain, route options for vehicles, lane markings, number of lanes, and weather conditions etc. (Kim and Yang, 2017). These may also include either a country road or highway, presence of fog and other road users such as pedestrians.

In each of the designed scenarios, a variety of agents (vehicles and pedestrians) besides subject vehicle are integrated and generate a certain degree of complexity with or in the related different dimensions. Other vehicles show various driving behaviours (speed and routes) generating interaction and satisfying connectivity. Due to their individual motion, the constellation of the additional agents (vehicles and pedestrians) changes with time integrating the dynamical dimensions into each scenario. The scenarios are also polytelitic because the driving actions (such as steering, breaking, throttling) possible for the subject vehicle at each point in the scenario depend on the driver's prioritization of goals. Along each route, there is fog, and some roads are curved, making vehicles and pedestrians ahead to not be immediately visible. These features integrate the intransparency dimension into the scenarios. Throughout each scenario, the specific actions to take to finish the drive depends on subject vehicle driver's decisions. This fulfils the variability of the goal dimension.

Five example scenarios are designed based on the dimensions of complex dynamical systems. In each scenario, there are specific situations known as critical situations where the ADS is unable to continue control of the vehicle and issues a RTI to the human driver. Each scenario has three difficulty levels (I to III) of critical situations. These levels of critical situations steadily increase the effect of features that are related to one or more dimensions of complex dynamical systems. In other words, the difficulty of a level II is higher than those of a level I and so forth. Altogether, there are fifteen critical situations.

Table 2 describes specific features of critical situations that results in the issuance of a RTI and illustrates how their difficulty increases row wise (from left to right).

Scenario 1: Fixed obstacle ahead on a highway: This scenario is set on a three-lane dual carriage highway with speed limits ranging from 70 Km/h to 130 Km/h. In each level of critical situation of this scenario, the ADS issues a

takeover transition because of a stationary vehicle ahead on the right lane. Due to the presence of fog in the scenario the stationary vehicle is not visible from afar. This generates intransparency for the driver when the RTI is given. In Level I critical situation, the speed of the subject vehicle is 80 Km/h and there is no surrounding vehicular traffic besides the stationary vehicle when the RTI is issued. In Level II critical situation, the speed of the subject vehicle is increased to 130 Km/h and there is still no surrounding vehicular traffic at the time the RTI is issued. Increased speed increases the dynamics of the situation and the manoeuvre difficulty during takeover. In Level III critical situation for this scenario, the speed of the subject vehicle is maintained at 130 Km/h, but a leading vehicle is introduced in the middle lane (front left side of the subject vehicle). The introduced vehicle generates a decision constraint which increases the effect of the complexity dimension.

Scenario 2: Slow vehicle ahead on a highway: This scenario is also set on a three-lane dual carriage highway with speed limits ranging from 70 Km/h to 130 Km/h. In each critical situation of this scenario, the ADS issues a RTI due to a slowly moving vehicle ahead. Due to fog, the slow vehicle is not visible from afar. This generates intransparency for the driver when the RTI is issued. In level I critical situation of the scenario, the speed of the subject vehicle is 80 Km/h and there is no additional surrounding traffic at the time of the RTI. In Level II critical situation, the speed of the subject vehicle is maintained by the ADS at 80 Km/h, but a leading vehicle is introduced in the middle lane (front left side of the subject vehicle) at the time of the RTI. The introduced vehicle increases the complexity dimension and results in additional manoeuvre difficulty. In Level III critical situation, the speed of the subject vehicle is increased to 130 Km/h while retaining the leading vehicle in the middle lane (front left side of the subject vehicle). By increasing the speed of the subject vehicle in this RTI situation, the dynamics is also increased.

Scenario 3: Exit highway: This is also a three-lane dual carriage highway scenario with several speed limits ranging from 70 Km/h to 130 Km/h. The ADS issues a RTI to exit the highway which will involve making a right turn. In Level I critical situation, the ADS issues the RTI to exit the highway while the subject vehicle is on the right lane (exit lane). The speed maintained by the ADS at this point is 50 Km/h. In Level II critical situation, the speed of the ADS at the time of the RTI is increased to 80 Km/h and vehicle is also on the exit lane. In Level III, the speed of the subject vehicle at the time of the RTI is further increased to 100 Km/h and the vehicle is also on the exit lane as written in the previous descriptions. Increased speed increases the dynamics of the situation and consequently the manoeuvre difficulty.

Scenario 4: Turn right on four-way intersection country road: This scenario is on a country road at the intersection of four junctions. The ADS issues a RTI in order to make a right turn into an adjourning country road. In Level I critical situation, the speed of the subject vehicle at the time of the RTI is 50Km/h. In Level II critical situation, the speed of the subject vehicle is maintained at 50Km/h, but a bike rider is introduced on the front right side of the subject vehicle at the time of the RTI. The introduced bike rider increases the complexity dimension of the situation. While in Level III, the speed of the subject vehicle is increased to 80Km/h, the bike rider on the front right side of the subject vehicle is retained and a pedestrian crossing the right adjourning road at the point of the turn is introduced. The increased speed, bike rider, and crossing pedestrian increases the dynamics and complexity dimensions of the situation. Consequently, the manoeuvre difficulty is increased.

Scenario 5: Turn left on four-way intersection country road: This scenario is also on a country road at the intersection of four junctions. The ADS issues a RTI in order to make a left turn into an adjourning country road. In Level I critical situation, the speed of the subject vehicle is 50 Km/h at the time of the RTI and there is no additional surrounding traffic. In Level II critical situation, the speed of the subject vehicle is maintained at 50 km/h and a vehicle approaching from the opposite adjourning road is introduced at the time of the RTI. The introduced vehicle increases the complexity dimension of the situation and the manoeuvre difficulty. In Level III critical situation, the speed of the subject vehicle is increased to 80 Km/h, the approaching vehicle from opposite adjourning road is retained and a pedestrian crossing on the left adjourning road at the point of the turn is introduced when the RTI is issued by the ADS. The increased speed and introduced pedestrian increase the effect of the dynamics and complexity dimensions. By implication, the manoeuvre difficulty is also increased.

Table 2. Scenarios and RTI-related critical situations for subject vehicle

Scenarios		Critical situation levels		
		I. Easy	II. Medium	III. Difficult
1.	Fixed obstacle ahead on a highway	• Speed: 80 km/h • No additional traffic	• Speed: 130 km/h • No additional traffic	• Speed: 130km/h • A vehicle in front left
2.	Slow vehicle ahead on a highway	• Speed: 80 km/h • No additional traffic	• Speed: 80 km/h • A vehicle in front left	• Speed: 130 km/h • A vehicle in front left
3.	Exit highway	• Speed: 50 km/h • Right lane	• Speed: 80 km/h • Right lane	• Speed: 100 km/h • Right lane
4.	Turn right on four way intersection country road	Speed: 50 km/h	• Speed: 50 km/h • A bike in front right side	• Speed: 80 km/h • A bike in front right side, • A pedestrian crossing at right turn
5.	Turn left on four way intersection country road	Speed: 50 km/h	• Speed: 50 km/h • A vehicle from opposite direction	• Speed: 80 km/h • A vehicle from opposite direction • A pedestrian crossing at left turn

3.2 Secondary tasks

Secondary tasks (STs) are activities that the driver can engage in while the ADS is controlling the vehicle. Requirements considered for the development of secondary tasks are, cognitively and visually engaging, and require motor activity (Kühn et al., 2017).

Considering the aforementioned criteria, three levels of STs namely reading, proofreading, and proofreading aloud (by saying correct word) are designed. The increasing complexity (multitasking) of the STs are explained with the theory of threaded cognition (Salvucci and Taatgen, 2008). Threaded cognition represents cognitive processes as process threads coordinated by a serial "procedural" resource and utilizes other available resources (e.g., perceptual and motor resources). "The theory defines a parsimonious mechanism that describes concurrent thought execution and projections of possible interference during multitasking" (Salvucci and Taatgen, 2008). In other words, it illustrates a clear increase in cognitive task complexity.

In threaded cognition, there are several cognitive resources namely, procedural, declarative, aural, visual, and motor resources (Salvucci and Taatgen, 2008). Each of these resources is capable of independent processing interference (Salvucci and Taatgen, 2008). Procedural resource represents procedural skill towards a goal. It always precedes the execution of another resource (Salvucci and Taatgen, 2008). Declarative resource retrieves static knowledge stored in memory. Aural and visual resources are perceptive resources. They acquire sound and visual information from the environment. While motor (manual) resource actuates necessary action (such as moving arms) in the environment. In other words, procedural and declarative resource utilize and process existing knowledge. Aural and visual resource acquire new knowledge and inference from the environment. While motor resource actuates decided action in the environment which is based on the output of the other resources.

Utilizing the theory of threaded cognition (Salvucci and Taatgen, 2008), the designed STs are explained in detail. Reading processes require procedural, declarative, and visual resources as illustrated in the first column of Table 3. Proofreading processes require procedural, declarative, visual, and motor (manual) resources as illustrated in the second column of Table 3. Proofreading aloud processes require procedural, declarative, visual, motor (manual), and vocal resources as illustrated in the third column of Table 3.

In line with the assumptions of threaded cognition (Salvucci and Taatgen, 2008), occurring resource conflicts (interference between processes) and a time delay (grey area Table 4) is generated for one process while the other executes. Since the procedural resource always precedes the execution of other resources, it is often a source of conflict. The interconnecting blocks represent the sequence and presence of time delay (not duration) within each process. The parallel process sequences clearly show increase in the complexity and by extension, increase in difficulty from ST 1 to 3.

If there is no wrong word to highlight, the correction process of the proofreading task (second column of Table 3) returns to the beginning of the thread after the "declarative: retrieve instruction" step. While in the proofreading aloud task (third column of Table 3), the vocal thread occurs only when there is a wrong word detected, hence why it begins alongside the "Procedural: initiate movement" step. The process sequence of each task is repeated for each word.

4. SUMMARY AND OUTLOOK

This paper discusses principles, assumptions, and procedures applied to design scenarios, critical situations and STs. These designs are intended to understand the scope of the variables that influence driver takeover performance in conditional driving automation. Features of these variables such as speed, situation complexity, and others have been observed from previous studies to influence driver takeover performance.

Table 3. Secondary tasks (STs)

Proofreading aloud (ST 3)		
Proofreading (ST 2)		
Reading (ST 1)		
Procedural: attend word	(Waiting until procedural is free)	(idle)
Vision: encode word	Procedural: retrieve instruction	(idle)
Procedural: do lexical access	Declarative: retrieve instruction	(idle)
Declarative: lexical access / Visual: encode word	(idle)	(idle)
Procedural: retrieve syntax	(idle)	(idle)
Declarative: syntax element	(idle)	(idle)
Procedural: attach syntax	(Waiting until procedural is free)	(Waiting until procedural is free)
(idle)	Procedural: initiate movement	(Waiting until procedural is free)
(idle)	Manual: highlight text	Procedural: retrieve instruction
(idle)	(idle)	Declarative: retrieve instruction
(idle)	(idle)	Procedural: retrieve tone response
(idle)	(idle)	Declarative: retrieve word
(idle)	(idle)	Procedural: respond to instruction
(idle)	(idle)	Vocal: say word aloud

The driving scenarios are modelled as complex dynamical systems based on known dimensions of complex dynamical systems. These dimensions of complex dynamical systems include, complexity, connectivity, intransparency, polytely, dynamics, and variability of the goal situation. To illustrate these effects, examples are discussed to design five scenarios, each with three levels of critical situation to provide suitable insights into the scope of variables affecting takeover performance.

The next step is to realize the scenarios and STs in a suitably designed experiment. Data from different combinations of scenarios and STs will be analysed to identify the different effects influencing driver behaviour. Identifying effects may enable determination of suitable RTI time online in takeover situations.

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