the benefits of using gameful design to increase user engagement. Section 3 discusses the impact of the use of a gamified interactive system on user tasks. Section 4 presents the task-models-based approach for the design of automation and game elements. Section 5 illustrates the proposed approach with a simple example based on the Mackworth clock experiment. We highlight the fact that this task is representative of monitoring tasks in industrial contexts. Section 6 concludes the paper and presents perspectives for future work.

2. Gameful design and engagement

Although gameful design and gamification techniques have not been studied evenly across application domains (most of the contributions come from the application domains of education and health), Seaborn and Fels [11] surveyed the literature and established that the results of gamification are mostly positive. They highlight that gameful design, including gamification, raise engagement and user performance. Indeed, a study on the gamification of the tutorial of the AutoCAD 3D objects modelling application [11] reported higher subjective engagement levels with the gamified application, and that users performed a set of testing tasks from 20% to 76% faster after using the tutorial with the gamified components. Gameful design can also encourage participation and collaboration with other users as demonstrated in the context of online learning [13]. These examples (and many other ones) show that the range of potential benefits of gameful design is quite wide if design choices are carefully elicited.

Gameful design requires fine-tuning of the game mechanics that are integrated in the interactive system, and game elements have to match what the user is able to perform in the context of use. Wilson et al. [13] argue that some design choices may be counterproductive and that engagement and motivation may vary a lot depending on the type of game element. Adding artificial challenge to a system supporting functional needs engenders frustration [4]. Moreover, Korn et al [5] showed that in an industrial environment, some gamification elements may improve production speed but may also increase the error rate.

3. Impact of gameful design on user tasks

As stated above, adding game elements and challenges to motivate the user leads to add additional objectives and tasks to perform with the interactive system. These additional tasks interleave with work tasks, and have thus to integrate in a consistent manner with them in order to avoid frustration and errors (especially capture and interference ones). Moreover, the design of game elements also requires identifying automation opportunities (for these game elements), with the objective of increasing the overall usability of the system but also to make sure that proposed challenges are important and motivating experiences for the user [4].

Gameful design for interactive systems at work thus requires being able to describes exhaustively and systematically:

- User work tasks;
- User tasks while interacting with work automation;
- User tasks to reach game elements objectives;

Analyzing all these elements together is also critical in order to detect conflicting elements.

4. Task models for the design of automation in both gamified and work tasks

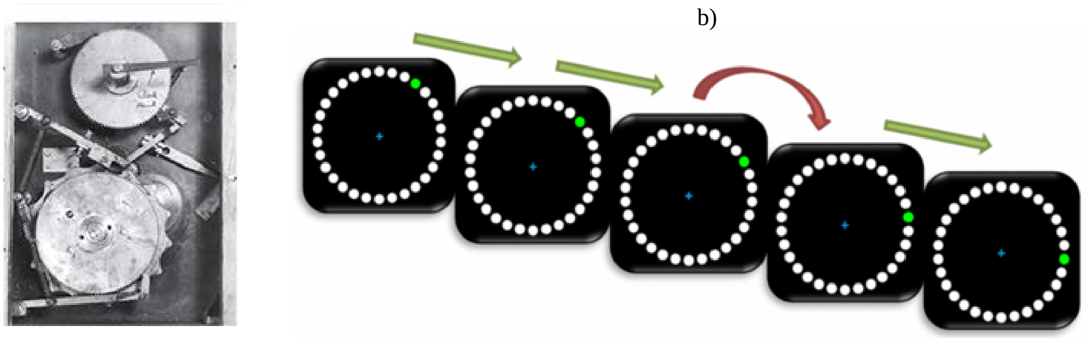
Existing gamification and gameful design methods rely on the identification of user tasks [1, 4, 13], but there is very little information about how to describe those tasks beyond text-based sequential lists of action.

We propose a task-models-based systematic approach for the identification of both tasks coming from game elements and the ones coming from work-related activity. Together with these task models we make explicit automation aspects (especially migration of tasks from the user activity to the system). Task models consist in a graphical, hierarchical and temporally ordered representation of the tasks the users have to perform with an interactive application or system in order to reach their goals. Task models is one of the very few means for describing explicitly and exhaustively user tasks [9]. Task models support several different stages of interactive systems design and development (e.g. user roles identification, system functions identification, user interface design, testing, training program design…) which requires the involvement of various stakeholders (e.g. human factor experts, system engineers, software engineers). The expressive power of the task modelling notation is critical for performing analysis on the models produced. Indeed, what is not represented cannot be analyzed. In this paper we use the HAMSTERS|XL notation [9] which is able to describe many types of task such as user task (cognitive, perceptive, and motor), abstract tasks, interactive tasks (input, output) and system tasks. Distinction between user and system task is critical for the current paper as this is how automation, using migration of tasks in functions can be represented. In addition to tasks, HAMSTERS|XL makes explicit in models the representation of information and knowledge required for performing each task. HAMSTERS|XL task models also enable the explicit and exhaustive description of allocation of tasks and functions between users and interactive systems [2, 9]. This makes them a perfect candidate for describing the user tasks at work and the user tasks to achieve objectives of the game elements, as well as the user tasks to interact with work automation and the user tasks to interact with game elements.

5. Illustrative example: The Mackworth clock

The Mackworth clock is an interactive system designed and developed to study the performance of operators monitoring information on airborne radars [7]. The system was developed to build experiments to assess vigilance capabilities of human being while monitoring autonomous systems. The Mackworth autonomous system (presented in Figure 1 a)) includes a green point, which moves in steps every second (like the second hand of a clock). In the experiment, at irregular time intervals, the green point moves the double of the usual distance (jumps one step). The operator has to detect this unexpected movement (representing a problem or a failure) and to press a button to prove that the malfunction has been detected.

b)



a)

Figure 1: Original Mackworth Clock from [1] and modified Mackworth Clock from [8]

Figure 1 b) presents a modified and digitalized version of the Mackworth clock. We chose to present it because it makes more explicit (as a symbolic representation) how the Mackworth autonomous system was functioning.

The hypothesis behind this experiment was that human performance in detecting malfunctions would decrease over time. Indeed, the study of performance of operators monitoring this autonomous system confirmed the fact that attention and vigilance decrease over time. The main outcome of this study was to propose identify the best compromise between the duration of the monitoring period (the watch-time of the operator) and the errors. In the following sections, we discuss the opportunity to alter this experiment adding game elements to the monitoring task to assess the possible increase of attention and vigilance for longer monitoring tasks.

5.1. Task model based gameful design of a new version of the Mackworth Clock

We selected the gameful design method called "The lens intrinsic skill atoms" [4] because this method provides a practical and detailed set of steps. Furthermore, this method integrates several major concepts identified as requirements for gameful design, amongst which **designing for basic need satisfaction (specifically competence)** and designing around inherent **skill-based challenges**. Figure 2 presents the main steps of this gameful design method. It is composed of five main steps respectively named Strategy, Research, Synthesis, Ideation and Prototyping. Each step is decomposed in several activities, and for our illustrative example, we focus on the activities that benefits from and can be described using of task models. These activities are 2a) Translate user activities into behavior chains and and 3a) Formulate Activity-Challenge-Motivation triplet systematically, which we refine using task model support. We also refine step four of the method and propose the activity task model based ideation.

INNOVATING	EVALUATING
1 Strategy	
a. Define target outcome and metrics	
b. Define target users, context, activities	
c. Identify constraints and requirements	
2 Research	
a. Translate user activities into behavior chains (optional)	
b. Identify user needs, motivations, hurdles	
c. Determine gameful design fit	
3 Synthesis	
a. Formulate activity, challenge, motivation triplets for opportune activities/behaviors	a. Identify skill atoms of existing system for opportune activities/behaviors
4 Ideation	
a. Brainstorm ideas using innovation stems	a. Brainstorm ideas using design lenses
b. Prioritze ideas	
c. Storyboard concepts	
d. Evaluate and refine concept using design lenses (optional)	
5 Iterative Prototyping	
a. Build prototype	
b. Playtest	
c. Analyze playtest results	
d. Ideate promising design changes	
Repeat steps a-d until desired outcome is achieved	
Increase prototype fidelity as playtest results approach desired outcome	

Figure 2. Five steps in gameful design from [4]

5.2. Translate user activities into task models (beyond behavior chains)

In the method "The lens intrinsic skill atoms", the behavior chains are to be used when activity is complex, because they are useful to "*deconstructs complex activities into chains of behaviors by different actors*" [4]. It is important to note that our proposed approach goes further that the concept of behavior chains. Task modelling enables to go beyond the decomposition in a set of event sequences, as it enables to breakdown all possible activities, as well as their hierarchy and all of their possible temporal interleaving (sequence, interleaving, interruption…).

Figure 3 presents the detailed description of the tasks the operator has to perform to monitor the clock. The main goal, represented at the top of the task model, is "Monitor clock". Under this main goal, the temporal ordering operator "|||" named concurrency has two branches that describe the tasks performing in parallel. On the left branch under the main goal, the system updates the clock every second (abstract system task "Update numeric watch" with an incoming arrow from the calendar event

“Every second”). This task decomposes in a sequence (temporal ordering operator “>>”) of a system task (a choice, indicated with the choice temporal ordering operator “[]”, between the tasks “Update to next” and “Update (malfunction)”) and the interactive output task “Display green point” which uses the output device “screen”. The system tasks update the value of the software object “position of green point”, which is required to perform the system output task “Display green point”. In the right branch under the main goal “Monitor clock”, the abstract iterative task “Monitor green point” decomposes in a sequence of user tasks. First, the user performs the perceptive task “Look at green point” using the output device “screen”, which produces the information “current position of green point’. Then the user performs the cognitive task “Recall previous position of green point” using the information “Memorized position of green point” and producing the information “previous position of green point”. Then the user performs the cognitive analysis task “Compare previous and current position” using both information “current position of green point” and “previous position of green point”. This task produces the information “size of shift”. Then, the user performs the cognitive analysis task “Analyze if shift is standard or not” using the information “size of shift” and the declarative knowledge “Standard shift is +1”. Then from the result of this analysis task, the user makes a choice (described using the choice temporal ordering operator “[]” combined with the test arcs on the value of the information “shift type”). If the shift type is standard, the user decides not to do anything. If the shift type is different from standard, then the user decides to press the response key, and then presses the response key. At last, the user performs the cognitive task “Memorize position of green point” which produces the information “Memorized position of green point”.

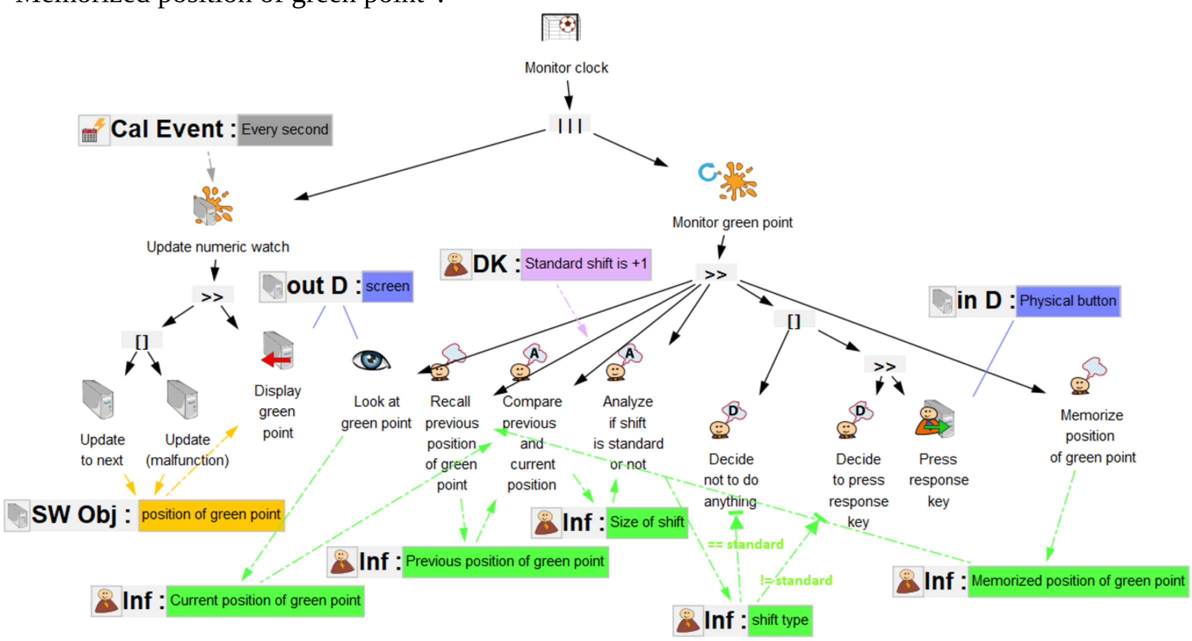


Figure 3. Task model describing the tasks to “Monitor clock”

5.3. Formulate Activity-Challenge-Motivation triplet systematically

The term “activity” refers to the tasks the operator will have to perform. This part of the method thus enables to identify systematically the possible motivations of the operator for the tasks, as well as inherent skill-based challenges of the tasks. Table 1 presents the list of activity (task) – challenge - motivation triplets produced using the task model. We produced this table by systematically going through the user tasks in the task model, and associating to each of them a relevant challenge and a relevant motivation.

Table 1
List of Activity-Challenge-Motivation triplets produced using the task model

Task (activity or behavior)	Challenge	Motivation (would require interviewing the operators, we cite examples from [3] and [12])
Monitor the clock	Detect all of the malfunctions	Example of motivation is incentive
Look at green point (visual perceptive task)	Be attentive, always stare at the clock	Example of motivation is immersion
Recall previous position of green point (cognitive task)	Recall the green point last position, do not confuse with other previous position	Example of motivation is to use special abilities
Compare previous and current position (cognitive analysis task)	Evaluate the right distance between the positions	Example of motivation is self-achievement
Analyze if shift is standard or not (cognitive analysis task)	Identify that the distance matches a standard shift	Example of motivation is acquiring skills
Decide not to do anything (cognitive decision task)	Identify that the distance matches a double shift	Example of motivation is fear of not being at the same level of competence as others
Decide to press response key (cognitive decision task)	Take appropriate action plan	Example of motivation is to feel engaged in protecting the organization
Press response key (interactive input task)	Correctly press the response key, do not slip	Example of motivation is fear of being laughed at
Memorize position of green point (cognitive task)	Memorize the position of the green point	Example of motivation is to feel in full possession of one's abilities

5.4. Task model based ideation

The method "The lens intrinsic skill atoms" guides the designers using questions when brainstorming design options. In particular, the questions "*What challenges can be removed through automation or improving usability?*" and "*What challenges remain that the user can learn to get better at?*" highlight that automation is also a tool when gamifying an application. On one hand, the main goal of the user task is to monitor the clock and the challenge of being attentive and staring at the clock should remain (framed row in Table 1). On the other hand, the "Recall previous position of green point" and "Memorize position of green point" may be difficult and error-prone, we thus propose to migrate them from the operator to the system. The automation of these work tasks decrease the number of tasks to perform for the operator. Figure 4 presents two screenshots to illustrate this proposal.

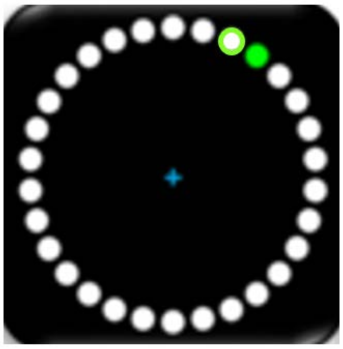


Figure 4. Illustration of the design proposal for automating operator's work

Figure 5 presents the task model modified for this automation proposal. In the left main branch of the model, we added two system tasks: an output system task named "display previous position of green point", as well as a storing system task. We also added a new software object "stored position of green point" to describe that the system will be storing the value of the previous position instead of the user doing it. In the abstract iterative task "Monitor green point", we replaced the cognitive task "recall previous position of green point" with the perceptive task "Look at previous position of green point", and removed the cognitive task "Memorize position of green point", as well as the associated memorized information "Memorized position of green point".

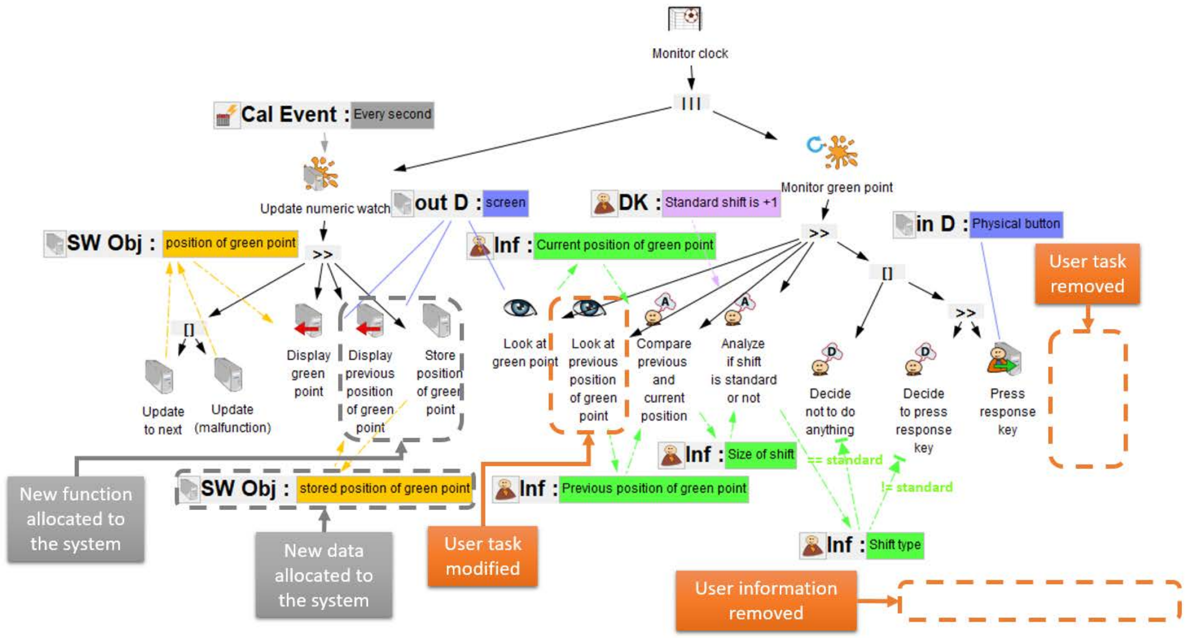


Figure 5. Task model modified for the work automation

This proposal of work automation should decrease cognitive load but may lead operator to be less attentive. We thus propose to integrate a game element, focused on a continuous input from the operator, to increase immersion. The game element the continuous tracking of the green point using a mouse pointer. The operator has one hand on the mouse device and has to move the mouse pointer to the green point each time the green point shifts. Figure 6 presents three screenshots that illustrate this design proposal. At the bottom of the screens, a panel indicates the total time on the green point and the total time outside of the green point.

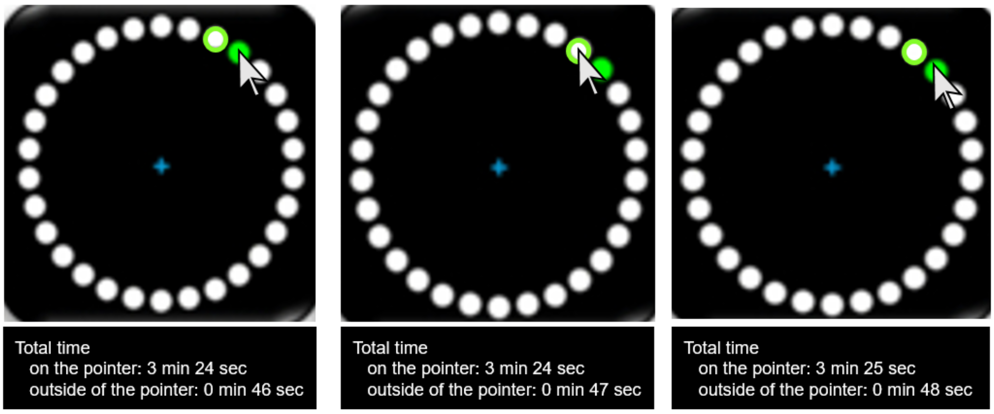


Figure 6. Illustration of the game element added to the modified Mackworth Clock

Figure 7 presents the task model modified to include the tasks related to the game element “mouse pointer tracking using a mouse device”, as well as the automation of work (explained previously). In the left main branch, we added the system output task “Display mouse pointer” which requires the software object “Mouse pointer position”. In the right part of the model, we added a new branch which main task is “Monitor mouse pointer” and is iterative. This task is part of the abstract iterative task “Monitor green point and mouse pointer”. The temporal ordering operator “|=|” (order independent) means that the operator can perform the abstract task “Monitor green point” first and then the abstract interactive task “Monitor mouse pointer”, or that the operator can perform the abstract task “Monitor mouse pointer” and then the abstract task “Monitor green point”. It decomposes using the same pattern as the green point monitoring task, but for the mouse pointer. The user first performs the perceptive task “Look at mouse pointer”, which produces the information “mouse pointer position”. The user then performs the cognitive analysis task “Compare mouse pointer position with green point position”, using both the information “current position of green point” and “mouse pointer position”. This task produces the information “mouse pointer position relative to green point”. Depending on the value of this information, mouse pointer is on green point or mouse pointer is not on green point, either the user will perform the cognitive decision task “Decide not to do anything” or the cognitive decision task “Decide to move the mouse pointer” followed by the interactive input task “Move mouse pointer”.

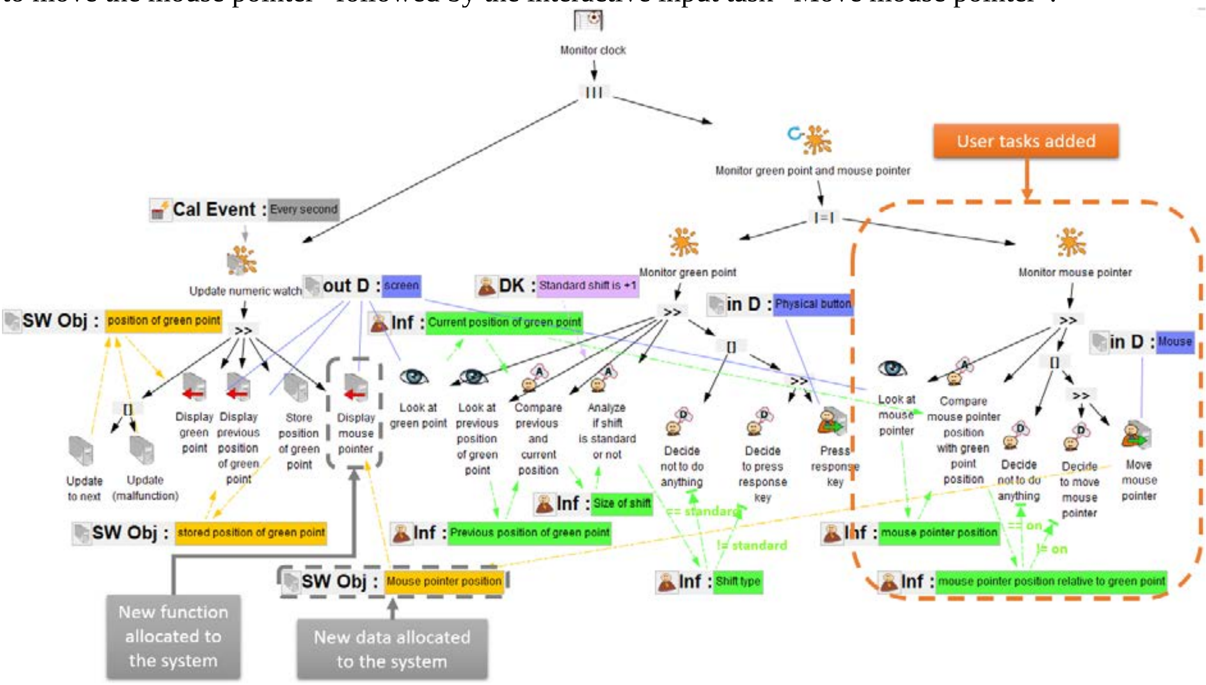


Figure 7. Task model modified to integrate both automation and game element

This task model helps to figure out the impact of the game element on the operator's tasks. We see that the new set of tasks that we introduced represents as many tasks as the set of tasks to monitor the green point and that this set of tasks interleaves with the work task, and share a common information to process for the tasks (Information "current position of green point" at the bottom in Figure 7). This confirms that the design proposal should increase the operator's workload while helping the operator to focus on the main goal.

By supporting the precise comparison of the original work tasks with the tasks altered by adding work automation and game elements, we argue that a task models based approach enables to identify relevant automation and gamification opportunities. The level of precision of task descriptions enables to filter out tasks that should be migrated to the system and tasks for which gamification will benefit to user performance and engagement. In that way, it supports reaching an optimum level of workload as exemplified in Figure 8.

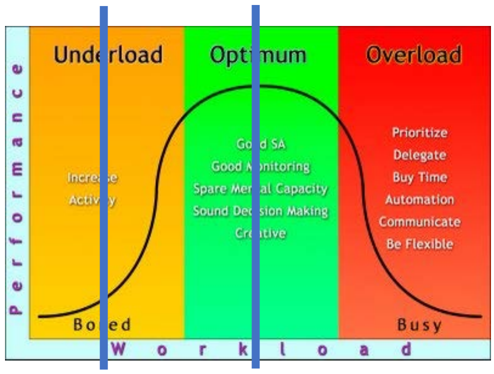


Figure 8. Using Yerkes-Dodson curve as a mean to represent evolution of user engagement and performance when game elements are added to work tasks

6. Conclusion

This paper has presented the potential benefits of using game elements interleaved with operators' work in order to increase user experience and engagement of operators. We argue that describing how these game elements transform the operators' work is critical in order to be able to assess the impact (positive and negative) of the activities added by the game elements on operators' work.

We have revisited the Mackworth clock experiment which is centered on the monitoring (by an operator) of an autonomous system. We took the position that degradation of the monitoring performance of the operators was related to a loss of engagement, and an increase of boredom and was due to the lack of active participation of the operator on the system.

To improve performance we decided to integrate in the work tasks additional tasks related to game elements added to the system. We used the HAMSTERS|XL notation to describe the original and the altered task models and used these models to demonstrate the higher engagement of operators when game elements are added.

This early work is a first step toward a more generic approach to improve operators' performance when, for instance in the context of automation, user activity is reduced to monitoring and supervision of autonomous systems. This approach proposes to add non-work activities to keep the user active and aware of the situation. We represented the expected results in a schematic way on Figure 8 where Macworth Clock is positioned in the underload region while the clock with the game elements is positioned in the optimum region.

There are several perspectives for future work. First, the modelling technique, beyond supporting the analysis of work automation, could also support the analysis of automation in game elements and the impact on user tasks. This would enable to differentiate the impact of work automation from the impact of game elements automation on user tasks. Then, the proposed task-model based approach could be applied to the whole method "The lens intrinsic skill atoms", this by including steps that require users in the loop (e.g. interviews and evaluations). The main expected benefits of such complete integration of task modelling within the gameful design process is to ensure systematically precise identification of the most appropriate candidate tasks for gamification as well as fine tuning of the design solutions.

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