EUROPEAN UNION AGENCY FOR RAILWAYS

German Centre for
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AUTOMATION MYTH #3

Automation makes the task easier (and therefore improves performance)

Automation and mental workload: Why it is important to get the balance right

SUMMARY

It is easy to assume that introducing automation into a task would decrease the mental workload on the operator – after all, if they are doing less, then the task must be easier. It also makes intuitive sense that an easier task should be performed more effectively. However, neither of these assumptions are necessarily true. Automation paradoxically has the potential to both increase and decrease mental workload, depending on the circumstances. Furthermore, decreasing workload can actually put an operator into an underload state, which is just as bad for performance as overload. We have learned these lessons in the aviation and, more recently, automotive industries; as accident reports demonstrate, we are now starting to see their impact on the railway with the introduction of Automatic Train Operation and other automated systems. The key in helping an operator to work at their best is to find a way to optimise their mental workload – which may mean thinking differently about automation.

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INTRO

Picture the scene: it is the not-too-distant future and you are driving your brand new car, which has come equipped with all of the latest ‘autopilot’ features, so it can both steer itself and control its speed. This is the first time you have taken the car for a drive, and you decide to try these features out on a stretch of highway. You get the car up to highway speeds, press the ‘autopilot’ button, and – voilà! – the car is now in control. Seems easy, right? You can just relax and enjoy the ride.

But you are a conscientious driver, you have read the operating manual for the autopilot system, and you know full well that you still have responsibility for ‘driving’ safely even when the system is engaged. You cannot take your hands off the steering wheel because, if you do, the car will sound an alarm and threaten to disengage the autopilot. If you look away from the road ahead, the driver monitoring system will detect this and, again, sound the alarm. And all the while, you have to be alert for any situations that the autopilot is not designed to cope with, and be ready to take over control at a moment’s notice.

This is all starting to sound a lot more difficult than you thought. You are having to be an attentive driver without actually being in control of the vehicle. Surprisingly, that feels harder than just driving the car yourself. But it is even more complicated than that because, as well as watching the road, you are also having to watch the autopilot system closely to understand what it is doing, and when it might want you to take over. This is a struggle, because the interface does not give you many clues as to what the system is ‘thinking’ – there is just a small icon to tell you that it is engaged.

While you are trying to figure this all out, another car suddenly pulls in front of yours and brakes sharply, aiming for the highway exit that is just coming up. This is more than your car's autopilot can cope with so it sounds its alarms. There is a moment's confusion in your head before you realise what is happening; instinctively, you press hard on the brakes and just manage to avoid colliding with that car in front. Your heart rate and your stress levels have rapidly increased, and you decide to follow the offending car off the motorway so you can stop and get your breath back.

AUTOMATION AND MENTAL WORKLOAD

Obviously the scenario above is a hypothetical one, but it is not entirely unrealistic. The point is, the popular assumption that automation will make the task easier (and, by implication, better) is not necessarily true when we still rely on a person as a fallback operator – and expect that person to be a reliable and attentive fallback. If they decide not to be so attentive, which may reduce their workload, then their performance is likely to suffer even more when they need to take over control from the automation.

Paradoxically, then, automation can both increase and decrease mental workload, even within the same task. Different aspects of the task can impose underload or overload respectively – experience with autopilots in commercial aircraft shows that the highly automated activities such as cruise flight can result in underload, whereas the more critical operations of take-off and landing can lead to overload (Endsley, 2015). There is also evidence that automation changes the nature of the task (Metzger & Parasuraman, 2005) and imposes qualitatively different demands across human information processing stages, perhaps increasing or decreasing workload associated with perception, decision-making, or response (Wickens et al., 2015).

Much of this results from the capabilities of automation technology – being unable to fully and completely relieve the task from the human, it often makes the easy tasks easier and the hard tasks harder, a situation that has been termed 'clumsy automation' (Lee & Seppelt, 2012). We know from decades of human factors research that both underload and overload are detrimental to performance (e.g., Young et al., 2015).

Underload can occur in an operator who is facing excessively low – but not entirely zero – mental demands, such as when supervising an automated system. What happens in this situation is that the operator's attention starts to degrade, so that their capacity to deal with anything unusual is reduced (Young & Stanton, 2002). The problem with underload then actually becomes apparent when there is a sudden increase in demand – such as the emergency situation faced by our hypothetical driver above – and this is now beyond the operator's reduced ability to cope. So reducing workload is not necessarily a good thing, if we are expecting the person to remain attentive and alert.

At the other end of the scale, overload can occur through the operator's interactions with the automation and the fact that it adds a new dimension to the task. Compared with controlling the task manually, automation increases complexity, requires the operator to integrate and interpret new information (Lee & Seppelt, 2012), and imposes a new set of monitoring demands. Surprisingly, this monitoring task actually creates high workload for a vigilant operator (Warm et al., 1996), and is difficult to sustain for prolonged periods. Moreover, a 'clumsy' approach to part-task automation can leave the human operator with an incoherent set of tasks remaining to take care of, which can also increase mental workload (Stanton et al., 2021).

All of this points to the idea that human mental workload should be optimised in order to achieve best performance (Young et al., 2015) – neither too high nor too low (see figure 1). For automation to avoid both overload and underload, it needs to be smarter in working with the operator as part of the same team (Reinartz, 1993). With more automation now making its way into train operations, railway signalling and elsewhere, this is an issue that the rail industry needs to take account of, as recent case studies demonstrate.

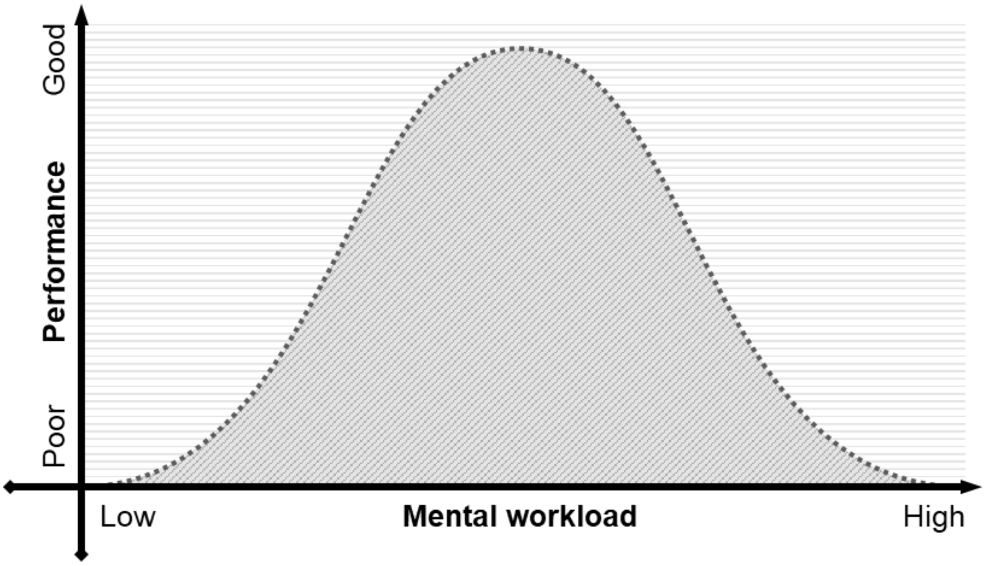

Fig. 1: 'Inverted-U' relationship between mental workload and performance (adapted from Young et al., 2015)

RAILWAY INCIDENTS INVOLVING MENTAL WORKLOAD WITH AUTOMATION

On the afternoon of 31 January 2018, a passenger became trapped in the closing doors of a London Underground train departing from Notting Hill Gate station in west London (RAIB, 2018). She was dragged along the platform and about 15 metres into the tunnel, suffering serious injuries as a result.

Seven months later, on 1 September 2018, another London Underground train travelled between Finchley Road and West Hampstead stations with doors open at ten passenger doorways (RAIB, 2019). Although nobody fell out of the train there were no injuries, the train had about 30 passengers on board and reached a maximum speed of 62 km/h during the 56-second journey between the two stations.

Both of these trains were operating in automatic train operation (ATO) mode, in which the train operator in the cab carries out station duties, while the train automatically transits from one station to the next. Between stations, then, the train operator simply monitors the train and track, while their task at stations is to operate the doors, monitor passengers getting on and off, and starting the train – a very repetitive task. The investigation reports for both incidents found that ATO played a key role in the causal analysis, with the train operators in each case seemingly affected by mental underload.

At Notting Hill Gate, the train operator was not aware of the trapped passenger before initiating the train's departure. This was in part likely because of the nature of the task, which resulted in him not consciously processing the available information. The ATO system presented the operator with a relatively low workload and repetitive actions at the station stops; this can invoke a cognitively automatic mode of responding, which reduces attention. As long as the task is consistent (that is, nothing is wrong), the operator performs it quickly and (apparently) efficiently. But when the situation changes and there is a critical event (as in this case), their reduced attention makes the operator vulnerable to missing the vital piece of information – hence being unaware of the trapped passenger.

The train operator at Finchley Road was similarly affected by mental underload. A door fault at the station presented an unexpected situation, which meant a sudden increase in workload for the operator after an extended period of potential underload. As a probable consequence, the train operator was unaware of the open doors and ended up bypassing the door interlock, so that he could depart the train. The report identified a possible underlying factor in the training of train operators, which 'did not adequately prepare them to manage the sudden increase in workload caused by the need to deal with faults, under time pressure, on trains operating in automatic mode'.

The recommendations from these investigation reports included supporting train operators in these circumstances to maintain attention as well as in dealing with sharp transitions from low to high workload.

Strategies such as breaking up the task with manual control may help to optimise workload and offset the impact of underload.

CONCLUSION

Automation is often predicated on reducing mental workload, with the assumption being that an easier task is better for the human operator. But this is not necessarily the case: underload is just as bad for human performance as overload and, in any case, in some circumstances automation can actually increase workload. As long as we expect a human operator to play some role in an automated system, it is actually better to design the system to optimise workload on the operator.

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