

Good Practice Guide on Cognitive and Individual Risk Factors

Synopsis:

The aim of this document is to raise awareness of the cognitive and individual factors that can influence the potential for driver error, the distinction between different categories of errors and violations, and to offer good practice guidance on the proactive management and mitigation of the human risks.

RS/232
Issue 1
August 2008

This document is the property of the Rail Safety and Standards Board Limited. It shall not be reproduced in whole or in part without the written permission of the Department Head of Railway Group Standards Management, Rail Safety and Standards Board.

Published by:
Rail Safety and Standards Board
Evergreen House
160 Euston Road
London NW1 2DX

© Copyright 2008 Rail Safety and Standards Board Limited

Good Practice Guide on Cognitive and Individual Risk Factors
RS/232 Issue 1
August 2008

Contents

Section	Description	Page
Part 1	Introduction	3
1.1	Purpose and scope	3
Part 2	Introduction and background	4
2.1	Human Factors defined	4
2.2	System safety	5
2.3	How to apply the information in this guide	7
Part 3	The human operator – the last line of defence	9
3.1	Human information processing	9
3.2	Perception	10
3.3	Attention	12
3.4	Memory	15
3.5	Decision making	17
3.6	Action	18
Part 4	Concentration and attention – limiting factors	19
4.1	Visibility, perceptual and vigilance factors	19
4.2	Mental workload / operational demand	20
4.3	Expectation and mental autopilot	22
4.4	Habituation	23
4.5	Distraction / preoccupation	23
4.6	Fatigue	26
4.7	Stress	28
4.8	Traumatic events	30
4.9	Individual factors	30
Part 5	Understanding the difference between human error and violations	35
5.1	Error classification	35
5.2	Errors in skilled-based performance	36
5.3	Errors in rule-based performance	37
5.4	Errors in knowledge-based performance	38
5.5	Violations	41
5.6	Cognitive classification of human error violation	43
Part 6	Risk mitigation techniques	47
6.1	Situation awareness	47
6.2	Risk Triggered Commentary (RTC)	54
Appendices		
Appendix A		57
Appendix B		60
Appendix C		61
Appendix D		63
References		64

1. Introduction

1.1 Purpose and scope

This document has been published by the Rail Safety and Standards Board. It replaces Appendix K 'Behaviour Identification Checklist' and Appendix N 'Behavioural and Human Factors Guidance – Practical Guidance for Drivers and Managers' contained within GO/RC3551 'Approved Code of Practice – Train Driving' which has now been withdrawn.

Although a stand-alone document, this Good Practice Guide is one of a suite of new publications that have been produced to replace GO/RC3551.

The intention of RSSB is to raise awareness of the cognitive and individual factors that can influence the potential for driver error, the distinction between different categories of error and violation, and to offer good practice guidance on managing and mitigating the risks (eg prior to an incident).

Information includes:

- a) The human information processing system and its inherent limitations (eg perception, memory, attention, decision making, action)
- b) Cognitive and individual factors that can increase the likelihood of driver error (eg expectation, habituation, distraction, automation, workload, fatigue, stress)
- c) The distinction between different error types and violations
- d) Risk mitigation techniques for drivers – situation awareness and risk triggered commentary.

The information in this guide is primarily based upon the role of train driver. However, as the document pulls together both generic human factors information (eg cognitive limitations, proactive identification of individual risk factors), as well as guidance specific to drivers, it will be of interest to a broad audience, including:

- Driver managers
- Train drivers
- Assessors
- Trainers
- Instructors
- Managers of other safety critical workers (eg signallers, trackworkers)
- Accident and incident investigators
- Occupational health professionals
- Those with responsibility for establishing and maintaining safety management arrangements.

The aim of the document is to encourage a shift away from a 'reactive' style of (driver) management (eg post incident), to a more proactive approach based on the recognition that errors are inevitable, and normal, and that all potential consequences need to be managed.

A proactive approach to error management can benefit organisations in a number of ways:

- a) Feed into and support the driver monitoring process by (i) increasing awareness and identification of human risks, and (ii) ensuring remedial action plans, developed to address performance issues are based on an accurate identification of the underlying causes(s) [1]
- b) Adopting a non-punishing approach to error management and communicating a formal understanding that errors will occur encourages an organisational 'learning culture' that has the support and buy-in of its employees
- c) Improve human performance
- d) Reduce risks
- e) Reduce frequency of human error
- f) Reduce consequences of human error
- g) Increase individual and organisational efficiency.

2. Introduction and background

2.1 Human factors defined

Human factors is an applied scientific discipline which draws on knowledge from engineering, psychology, ergonomics and physiology. In its broadest sense, human factors refers to influences on performance associated with people's interactions with their physical and social environments [2].

The Health and Safety Executive (HSE) define human factors as:

'the environmental, organisational and job factors, and human and individual characteristics which influence behaviour at work in a way which can affect health and safety'.

This definition can be represented as three overlapping spheres that represent the interaction between the individual, the organisation and the job itself (see Figure 1).

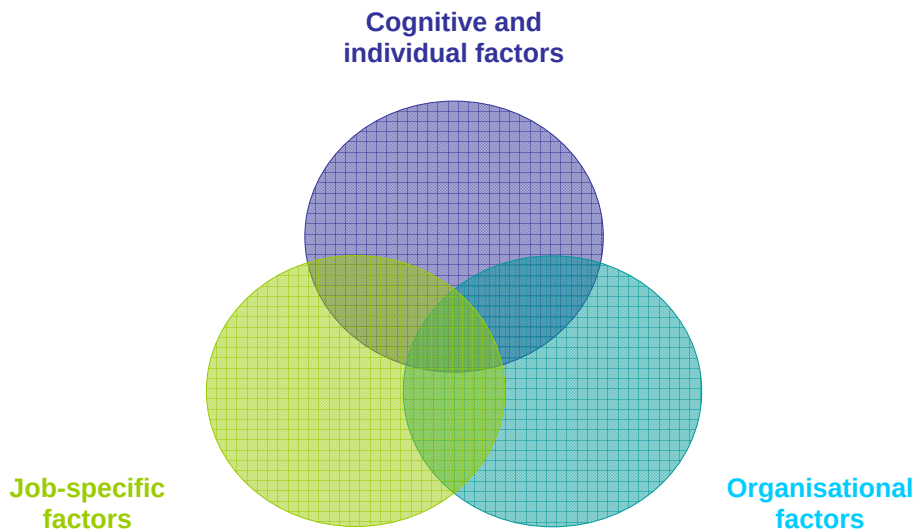


Figure 1 HSE model of human factors

Each sphere includes a range of factors that can influence performance. In train driving terms, this includes consideration of:

Cognitive and individual factors – eg driver alertness, attention, perception, situational awareness, personal issues;

Organisational factors – eg company culture, training, procedures, resources, teamwork;

Job-specific factors – eg signalling, train controls and instruments, communications.

As illustrated by figure 1, it is important to recognise that the factors that influence performance within each sphere can operate either independently and/or in interaction with factors in other spheres.

A popular framework that helps us understand and apply human factors is the SHELL model (see Figure 2).

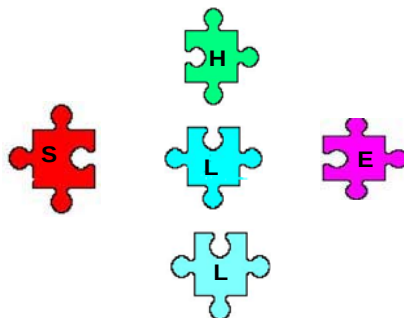


Figure 2: SHELL Model

SHELL is an acronym for software, hardware, environment and liveware. Figure 2 illustrates the five components and their relationship to each other. There are two Liveware elements, one to represent the central human operator (Liveware Central) and one to represent the interactions between people in a work context (Liveware Peripheral). In more detail, the five components are:

Software includes policies, procedures, rules, standards, checklists and information. Such factors can influence behaviour in a variety of ways. For example, inadequate or inappropriate documentation can lead to increased response times, create confusion or cause unnecessary distraction. Additionally, the clarity of rules and their perceived usability will affect whether they are followed properly.

Hardware includes the design and layout of equipment and tools and incorporates issues of usability both physically and mentally. For example, the design of controls can influence human performance as this will impact on an operator's handling and interpretation of equipment.

Environment includes the physical conditions in which work is carried out. Factors such as lighting levels, temperature and noise can all influence behaviour by acting as a distraction or, for example, discouraging effective communication and teamwork.

Liveware Peripheral considers human interactions. There are a number of factors which may affect human performance which result from working with other people, such as the effectiveness of team work, communication and employee-supervisor interactions. Interaction with other people also includes organisational factors such as supervision and the work environment which can affect how employees interact and work with each other.

Liveware Central includes factors related to human performance concerned with individuals' physiology, psychology and perception. Issues such as attention, workload, experience, knowledge, training and stress will affect performance because they influence how an individual perceives a situation, makes decisions and how much capacity they have to perform efficiently and safely.

2.2 System safety

The primary focus of this guide is on the cognitive (eg 'Liveware Central') and individual factors that can impair driver performance.

In human factor terms, driver (performance) errors directly due to 'liveware central', are often referred to as active failures (eg driving through a red light, perhaps due to distraction, workload or stress). The more indirect influences on performance error (eg 'software' – management factors; 'hardware' – poor system design; 'environment' – temperature; 'liveware peripheral' – communications) are often referred to as latent failures (or, more commonly, 'accidents waiting to happen') and are recognised as contributory factors to performance error.

Sometimes an active failure (perhaps the result of a rule violation – see section 5.5) is the root cause of a performance error, but often latent conditions are found to be at least partially responsible for the active failure that occurs.

To understand more about these (latent) contributory factors, and how they can come together to cause an accident, Professor James Reason, developed the now widely-known 'Swiss cheese' model of accident causation (see figure 3).

The model illustrates the fact that organisations have multiple layers of defence against hazards and errors (eg train protection warnings, training programmes, safety management processes, etc). It is only when failures in these defences line up with each other (eg poorly designed shift patterns, coupled with poor employee awareness of fatigue risks and other safety management failings, etc.) that an accident or incident results.

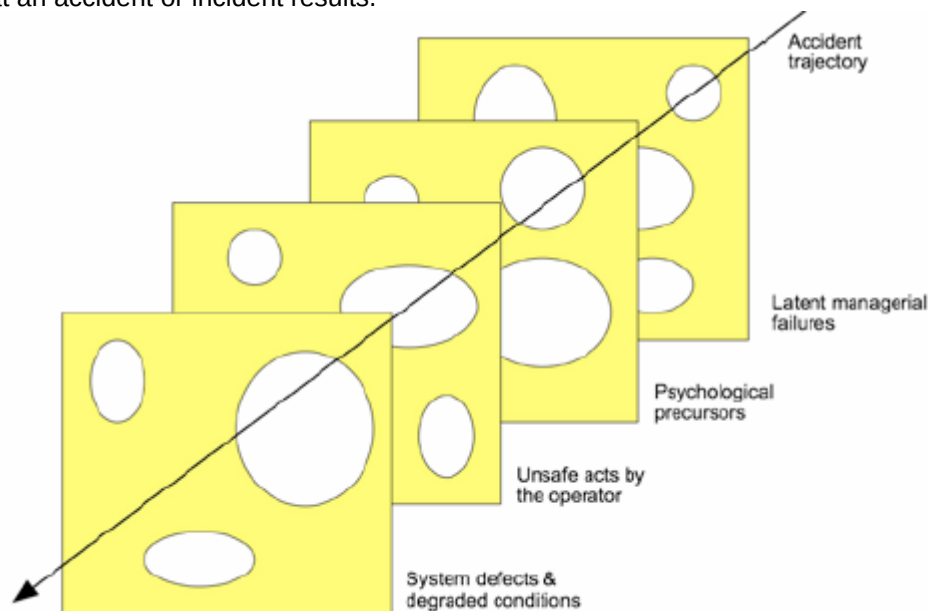


Figure 3 'Swiss cheese' model of accident causation

It is now widely recognised that accidents are the result of a complex chain of contributory events or factors, and that some of these contributors are permanently present in normal working conditions (see Appendix A for a summary of the individual, job-specific and organisational human factors that can contribute to errors and violations). This moves away from the notion of the operator (eg driver) being 'at fault', towards a genuine appreciation of the range of issues which may be detrimental to good driving performance.

In any safety critical environment, the human operator (eg driver) can be viewed as the last line of defence against failures at different system/organisational levels. Skilled and motivated operators of equipment can be very effective last-line defences under surprisingly adverse conditions as they search to prevent a bad situation getting worse. However, it is primarily the ways in which an operator perceives, interprets and reacts to the prevailing conditions that forms the basis of our understanding into the causes of (and potential solutions to) human performance errors.

For example, it is estimated that about 85% of signals passed at danger (SPADs) are attributable to human causal factors (see Appendix B '*Human Causes of SPADs*'). This is not surprising given that the task of train driving (and operation of the railway) relies heavily on humans interacting with equipment, and each other. Whilst safety systems such as AWS (Automatic Warning System), TPWS (Train Protection and Warning System) and DRA (Driver's Reminder Appliance) have all been introduced to automatically control the train (generally by making an emergency brake application if the driver does not provide a response), the driving task is still essentially a human one. It is difficult, therefore, for any human to complete the driving task, day in day out, without ever making an error.

SPADs, station overruns, excessive speeding and roll backs are all examples of events that can lead up to significant operational hazards on the railway (eg derailments, collisions). Accident investigations (eg Clapham Junction, Ladbroke Grove) repeatedly emphasise the contribution of human factors in precursory events and the influence of these on driver performance (eg fatigue,

distraction, poorly designed equipment, management failings, training gaps). For this reason, it is therefore essential that railway undertakings build on lessons learned and establish systems to identify, manage and mitigate the human risks. This should be done at the individual, job and organisational levels (see figure 1) to:

- a) Close any defensive gaps in the system (see Figure 3), and,
- b) To prevent an over-reliance on the primary control (eg driver) who, at times, will be prone to error.

Good practice example - SPAD Human Factors Hazard Checklist [3]

This is a checklist which is designed to ensure all possible human factors causes of SPADs are considered (including infrastructure and underlying operational issues). It provides a way of prioritising which features of a signal location are generating the greatest SPAD risk and identifies possible risk reduction/mitigation measures for each hazard. It helps investigators identify the contributory human factors problems associated with a SPAD incident and encourages them to consider the wider human factor issues associated, such as poor infrastructure and management failures, rather than simply focussing on driver issues such as competency, shift patterns, fatigue, etc.

2.3 How to apply the information in this guide

The intention of the RSSB in producing this Good Practice Guide is to encourage the industry to move away from the notion of the front line operator being *at fault*, to an appreciation of the various human factors that can influence performance at work.

The aim is that, by increasing awareness of the cognitive and individual limiting factors, that this knowledge will be used *proactively* by industry and integrated into everyday operations (at all levels) to identify, manage and mitigate the risks from human error. This means that, by having a better appreciation of what is 'going on out there', specific problems can be targeted as they emerge (eg training gaps, poorly designed equipment).

We know from preliminary research on driver management good practice, for example, that SPAD levels are lower for drivers whose managers spend more time on the following:

- a) Continuous assessments
- b) Ongoing (planned and unplanned) monitoring and observation (eg by manager/colleague, in cab, at stations, other vantage points, reassessments, simulations, etc)
- c) Using train recording data
- d) Supporting drivers (eg regular face-to-face discussions on driver performance and safety issues (separate from the company's safety briefing process))
- e) Following up on the causes of train delays
- f) Post incident report support and monitoring.

Where there is an indication of an underlying competency issue this may lead to the triggering of the 'Specially Monitored Driver' (SMD) process, which should include provision for managing sub-standard driver performance. Guidance is available from the Office of Rail Regulation (ORR) to assist railway undertakings maintain and develop competence, and manage sub-standard performance, as part of their Competence Management arrangements [1].

Managers should also be aware that there will be times in a driver's working life when personal issues or other behavioural factors may affect their concentration and ability to perform tasks which, if not addressed, may ultimately pose a threat to safety. The need for additional monitoring and support may therefore result from:

- a) Direct approach by driver
- b) Evidence of harassment from others

Good Practice Guide on Cognitive and Individual Risk Factors
RS/232 Issue 1
August 2008

- c) Absence due to stress or exceptional circumstances
- d) A driver experiencing a traumatic rail incident
- e) Manager's own observations which indicates safe performance is being compromised
- f) Awareness of drivers returning to work following personal issues (eg following a major incident, bereavement, divorce, house move, etc) [see Appendix C 'Recognising behavioural change'].

Where there is evidence of an underlying personal and/or behavioural issue, a driver's immediate fitness to continue duty should be assessed by a suitably qualified person (see Appendix C for a checklist of behaviours that may indicate an underlying personal and/or behavioural issue). If a driver is not considered fit to continue duty, an appropriate course of action should be agreed, which may include:

- a) Exceptional domestic, or other type of leave
- b) Sending them home for remainder of shift
- c) Referral to Occupational Health Service
- d) Transfer to alternative duties for a temporary period.

The success of any performance monitoring system is dependent upon correct identification of the underlying cause(s) and initiating appropriate remedial action. This should have the buy-in and support of the individual concerned, who should be an active participant in developing a programme to address any performance issue(s).

Railway undertaking are encouraged to formally communicate their commitment to and rationale for proactive error management and the driver monitoring process. This should be done in a supportive, blame-free environment and should include mechanisms for the confidential reporting of issues that may indicate an increased risk of (driver) error (eg outside of the SMD process).

3. The human operator – the last line of defence

You may have heard the phrase, 'to err is human'. Implicit in this statement is the fact that everyone, regardless of knowledge, experience or training, will, at times, be prone to error [4].

In order to understand why errors occur the following sections give a basic overview of how the human brain processes information.

3.1 Human information processing

'Information processing' is the term used by Psychologists to refer to the way in which humans:

- a) Receive sensory input from the external world (eg through our eyes and ears)
- b) Use this information to make decisions about what we have learnt
- c) Decide upon the actions we want to take.

Figure 4 illustrates a typical model of human information processing. It is based on the assumption of a series of mental (cognitive) operations that occur between information being received by the senses, decisions being taken and responses selected and executed.

For our purposes, the key components of interest are:

- Perception
- Attention
- Memory
- Decision making
- Action.

Such models are used to explore:

- Different types of error in more detail, eg whether due to a perceptual or memory failure, or as a consequence of having successfully interpreted the information but having failed to take the appropriate action, and;
- The influence of individual factors (eg stress, individual differences, fatigue and trauma) on human performance.

The key components of human information processing are described in more detail overleaf.

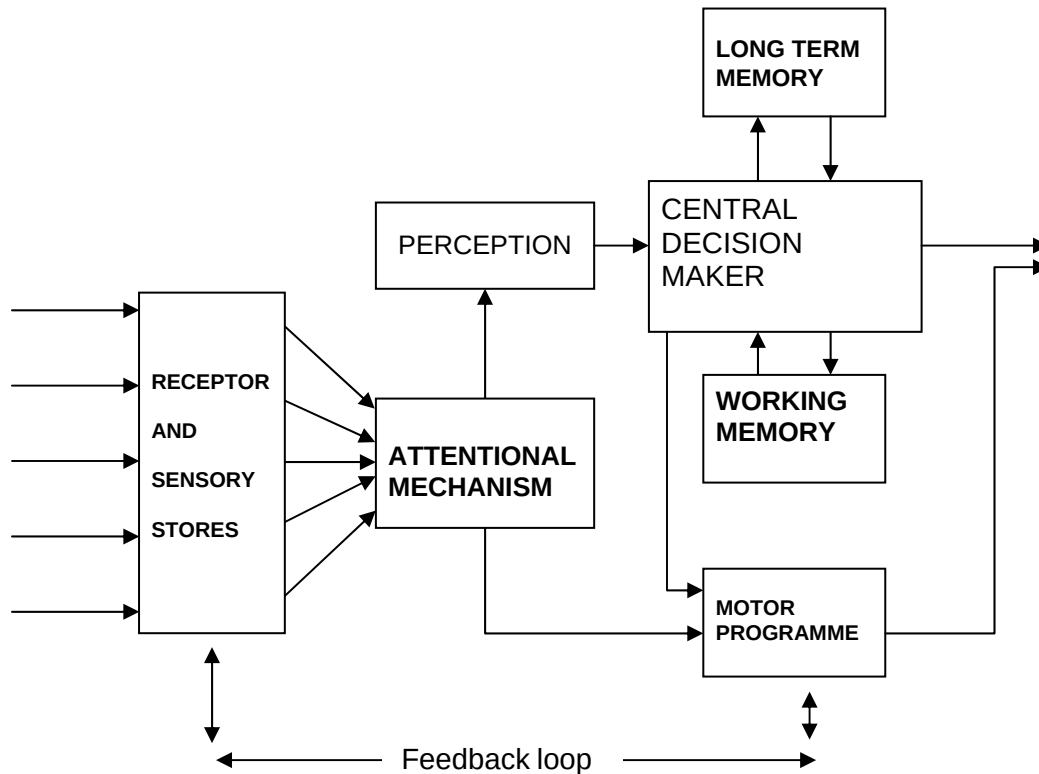


Figure 4 A model of human information processing

3.2 Perception

Perception involves the conversion of sensory information into meaningful structures which enables us to create an internal mental model or representation of the external world.

Visual and auditory information is stored briefly in either the visual or auditory sensory memory. An important point to note is that information stored in sensory memory will be quickly lost. In fact information stored in the visual sensory memory lasts between 0.5 and 1 second; information stored in auditory sensory memory lasts between 2 and 8 seconds.

The importance of sensory memories is that they enable us to retain information for a brief period of time until we have sufficient spare processing capacity to deal with new inputs.

The interesting point about human perception is that the mental models we create are not only dependent on both the quality and quantity of the information, but also on our experience and expectations of the world. What this means is that, having developed a mental model of the world, we tend to seek information which will confirm our 'view', at the expense of other contradictory inputs. This can lead to errors in visual and auditory detection, identification and interpretation.

Visually, for example, driving tasks include searching for new information that we may not be expecting to appear, such as people or animals on the line, and for anticipated information, such as aspects of signals. Drivers also need to communicate with signallers, on-board train crew, passengers and other rail functional groups. Such communication can be face-to-face or remote via radio or telephone. In all of these areas there is the potential for error.

There are both physiological as well as psychological components in the way that we perceive information.

In physiological terms, lighting is a key requirement for effective visual discrimination as people do not see well in the dark. However, whilst light will enhance visibility, it is not the only important factor. Other influences on visibility are physical and relate to factors such as contrast, brightness, shape, texture and placement.

Other important physiological attributes of perception include:

- a) Visual acuity – the ability to focus and see clear, sharp images, allowing people to see very fine or small detail, a characteristic of vision which declines with age
- b) Colour vision deficiency – whereby only a limited number of colours can be identified, the most common form of colour vision deficiency being an inability to distinguish between red and green
- c) Blindspot – refers to a spot on the retina that contains no photoreceptors; visual information that falls on this spot will not be processed into images.

All of the above three physiological features of perception can be detected by standard eye tests.

As stated above, in psychological terms, perception is not a passive process of simply absorbing and decoding incoming sensory information. If it were, people would have a very poor understanding of the environment as visual information would be a constantly changing, confusing mosaic of light and colour. Instead, the human brain takes the sensory input that bombards us all and actively creates from that the coherent world that is perceived and makes sense to us, based on people's experiences, expectations and emotions.

It is for this reason that some things in our environment will be much more visible than others at certain times. For example, it is a fairly common experience to notice things much more when they have direct relevance to something of current importance to the observer (eg a person buys a new red hatchback car and suddenly red hatchbacks seem to be very much in evidence despite the fact they were not noticed at all before the purchase).

The role of prior experience and expectation in the visual perception process cannot be overstated as it has an extremely strong influence on what people 'see'. In the face of new, incomplete or ambiguous information, people tend to use their own way of looking at the world to process and interpret what they see in a way that makes sense in a given context. This can be a major factor in why people make performance errors (see Part 5).

Humans also have a natural tendency to make what they will from visual stimuli as illustrated by numerous visual illusions (see Figures 5-7), all of which can be explained through perceptual processes.

Common features of perceptual processing include:

- Individuals filling in missing information (see Figure 5):

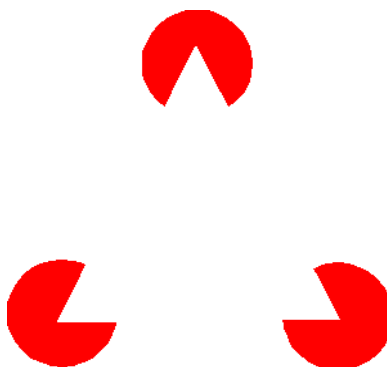


Figure 5 One whole or individual components?

- What the person regards as borders to distinguish figure (the meaningful element) from background (see Figure 6):

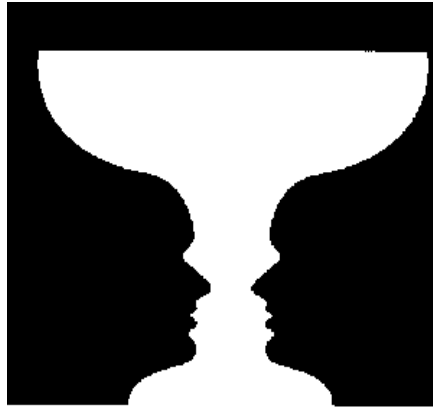


Figure 6 A vase or two faces?

- The way things are conceptually grouped together to form a 'gestalt' (whole figure) (see Figure 7). This will include consideration of: proximity (how close things are to each other); similarity (how similar they are to each other); common fate (whether or not they appear to be connected/interdependent); continuation (whether elements seem to create a single continuous form); closure ('filling in' of apparently incomplete objects):

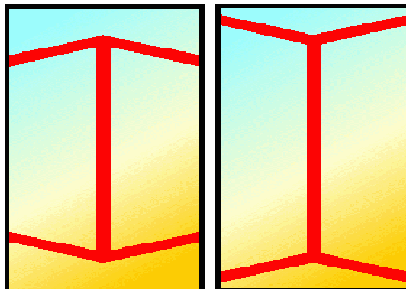


Figure 7 Which is the longer?

- How people adjust to changes in image size, shape and colour, etc. on the retina to perceive movement, distance, shadow, viewpoint.
- The ability to *select, focus, and divide attention* when a person is faced with various stimuli competing for attention (particularly if related to the same sense, such as sight). At some stage, one stimulus will become more powerful than another in attracting attention. When this happens, processing of the less attended information will not be fully effective.

3.3 Attention

The key point to note here is that our ability to attend to all of the information that bombards our senses is that it is *limited* by the *channel capacity* of attentional processing. The fact that our attention is limited means that we are unable to devote conscious thought or 'attend' to all of the stimuli that impinge upon us. For this reason, the human brain is capable of filtering information at an early stage of processing to enable us to select the stimuli that will be consciously perceived and used as the basis for thought and decision making.

- a) *Selective attention.* This refers to the process by which sensory inputs are selected to ensure that the information we want to process in detail is relevant to the task. Information we select and are receptive to will relate to the *context and other intellectual and emotional influences*. Personal values and interests will play a major role, as well as physical characteristics, such as size, brightness, movement, etc.

It would be unfortunate, however, if this process were so rigid that information not directly related to the task was always lost (eg failing to hear our name called whilst concentrating on an activity). In fact, people are rather good at detecting information of relevance to them, such as their name. This is due to the fact that, even if not consciously aware of it, information can still be *processed* and tested for importance. For example, apart from our name, some stimuli, such as loud noises and flashing red lights are particularly '*attention-grabbing*'. It is for this reason that they are important in the design of warning systems. However, the fact that we can be so easily *distracted* by stimuli in our environment does mean that we are vulnerable to error (see Part 4).

- b) *Focussed attention.* This refers to the width and intensity of attentional focus. For example, the narrower the width of our focus (eg when concentrating on a new or difficult task), the stronger our attention will be. Whilst this can be very adaptive in that the full capacity of our attention can be focussed on an immediate problem or piece of information, it does have the potential disadvantage that sometimes *relevant stimuli may be missed*.
- c) *Divided attention.* This refers to our ability to be able to 'switch' conscious thought between different sources of information. For example, a driver approaching a station will be required to divide his attention between looking ahead outside the train and looking down at the speed indicator. This ability to divert attention for the core task activity (eg driving), to a secondary task (eg speed indicator) enables performance to be continually checked and monitored using a process known as *closed loop feedback* (see Figure 8).

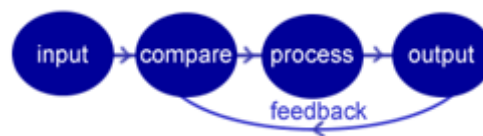


Figure 8 Closed loop feedback

It must be re-emphasised, however, that the detection and interpretation of sensory inputs will be greatly influenced by what we are expecting to receive. Decisions that have already been made, or information stored in short or long term memory may influence recognition of input in the sensory store. Moreover, when we become so consumed or preoccupied with the core task, the strength of our attention will be reduced and the ability to use other sources of information to monitor performance can go unchecked and lead to error.

The amount of attention available will also vary according to the level of:

- a) Physiological arousal, or *general alertness* (see Part 4). For example, attention can be affected by extended periods of high mental workload, leading to fatigue, by low arousal, due to the monotonous nature of a task, and also by environmental factors, such as cab temperature and noise levels.
- b) Level of skill acquisition (see 'automaticity' overleaf).

Good practice examples – managing attention

- *Personal* – the conscious steps that should be taken by drivers to manage attention, in accordance with training, needs to be both understood and undertaken. New recruits should take their conscious control one stage further and be instructed to talk to themselves (out loud) through the driving task (see 6.2).
- *Organisational* (training) – simulator exercises should include those novel and unusual scenarios, eg difficult shunt manoeuvres, that cause drivers to become distracted and lose attention.
- *Shifts* – as new drivers have higher cognitive workloads (see 3.3.1), further assistance should be given to enable these drivers to work their shift of preference. This may reduce the contributory factor of tiredness, caused by the difficulty of adapting to changing sleep patterns. All drivers should be aware that *continually* working the same shift/swapping shifts can also cause difficulties adapting to changing sleep patterns.
- *Communication* – regular time slots could be arranged for drivers to meet their manager(s) in small groups, to encourage exchange of information and improved communications. This would help reduce (inexperienced) drivers reluctance to ask for assistance when needed which can lead to inattention.
- *Environment* – air conditioning that can be adjusted by a driver would improve the cab environment by maintaining an optimum working temperature, thereby reducing the potential for fatigue. This would also remove the need to open cab windows, thereby reducing both noise and distractions arising from passenger queries.

3.3.1 Automaticity

On many tasks (eg driving a car), practice leads to a reduction in the amount of processing capacity required by the individual and may eventually lead to the execution of the task becoming *automatic*.

Automatic processing is defined as being fast, attention-free, unconscious and unavoidable. By definition, automaticity is the opposite of controlled processing, which is slow, attention-demanding, under conscious control and adaptable. For this reason, automaticity is associated with highly skilled performance.

For example, the initially demanding task of changing gear in a car will eventually be performed by a skilled driver with little or no conscious awareness. Skilled drivers can easily drive a car and maintain a conversation at the same time. All that is required is that the driver monitors their performance. Continuous conscious control is no longer required.

Automaticity is explained by the fact that practice and experience increase the knowledge base and lead to rapid retrieval of past solutions from memory. Experts perform by implicit anticipation (eg 'open-loop' behaviour), rather than by feedback. Novice performance, on the other hand, is characterised by a lack of knowledge. Automaticity is therefore associated with a situation of low uncertainty and high predictability.

The ability to automate behaviour brings a number of distinct advantages for performance. Expertise is commonly associated with efficiency, and is consequently seen as a positive indicator of performance. Automaticity is also useful in multi-task situations, as the automatic process hardly interferes with concurrent tasks. This also means that skilled operators are more able to cope with unplanned situations. It has also been cited as a prerequisite for situation awareness (see Part 6).

Unfortunately, our ability to 'automate' skilled behaviour is also open to error. This is due to strong, inflexible expectations that influence selective attention and the fact that automatic processes are unconscious and unavoidable. Performance decrements are especially apparent in such situations if the task has been learned by repetition, rather than understanding, as the operator cannot adapt to new circumstances. Moreover, if the demands of a task change (eg driving becomes difficult) then full

controlled attention would be necessary (eg operator is forced to resort to a feedback/novice strategy) to ensure flexibility in response (and hence any secondary activity, eg conversation, would have to stop).

The irony is that expert performance needs to be monitored in a controlled fashion if errors are to be detected and corrected, but that controlled processing does not by definition equate with expert performance. Only if the task is consistent and there are no problems, should automatic processing guarantee error-free performance.

Good practice examples – facilitating learning

- a) Rehearsal: organisations should encourage a culture in which drivers review information critical to performance on a regular basis, ie reading training manuals daily, regular Rule Book review. This should be reinforced by training/assessment/simulation exercises and material.
- b) Question and answer sessions with supervisory staff on an informal but regular basis.
- c) Transference of critical information to 'crib cards' by the driver to allow regular review during periods of inactivity and to facilitate the learning process.
- d) Noting main points of safety briefings for own personal use.
- e) Introduction of manager or trainer surgery hours to answer questions which arise after training has been completed.
- f) Introduction of 'study weeks' with a specific focus of attention each week, i.e. a different section of the Rule Book each week, followed by a review period or question and answer session.
- g) Increased practical applications, wherever possible, of theory learnt during training.
- h) Option for driver to request assistance during a shunt move not attempted previously, where the driver feels insufficiently conversant with the move.
- i) Learning by observation (modelling), eg learning what takes place simply by having the learner observe the appropriate response.

3.4 Memory

The memory system consists of working (or short term) memory and long term (or stored) memory. Both types of memory are crucial for train driving tasks.

3.4.1 Working memory

Working memory enables information to be retained for a short period of time. For example, drivers use working memory when repeating information to signallers and recalling the aspect of the previous signal.

In order to hold information in *working memory* a driver must direct attention to the process. If not attended to, information in working memory will be lost in 10 to 20 seconds. Such attention is achieved through the process of *rehearsing* the information to be retained. For example, a driver may continuously repeat the aspect of the previous signal to hold this information in working memory. The problem is that, even if the information is rehearsed, there will be a decay in working memory over time, which will become more pronounced as the amount of information held in working memory increases.

The reason for this is that the capacity of working memory is *limited*. We know from research that the maximum number of unrelated items that can be maintained in working memory, when full attention is devoted to rehearsal is roughly *seven*. This has important implications for the design of systems to be operated by humans.

Once this limit of about seven is exceeded, one or more items are likely to be lost or transposed through the process of *interference*. This causes information held in working memory to become replaced with the arrival of new information (eg a conductor talking to a driver may cause the driver to forget the aspect of the previous signal because they cannot rehearse the information whilst holding a

conversation), or confused by that which was previously stored (eg 'cat' may be recalled instead of 'mat').

It is for this reason that driver aids, such as the Drivers Reminder Appliance (DRA), are used to prompt the driver to check a signal has cleared, rather than rely on the driver's memory to store the information. For example, when a driver performs the act of switching on the DRA they can be said to be dividing their attention. It may be that by performing this action the driver reaches an overload in their working memory which would mean that the retrieval of the information (ie why they are switching it on) may be misplaced. Also, if at full working memory capacity, it is very possible that the driver will occasionally forget to complete the task (switching the DRA on) due to a simple distraction (eg some external event, or someone attempting to communicate with them).

Good practice examples – facilitating retention

- a) The number of items retained in working memory can be expanded by the *clustering* or '*chunking*' of related material (eg remembering a familiar telephone code such as 020 7 as 0207).
- b) *Chunking* unrelated items into groups of three and four, eg 055 2781, will assist the maintenance of items.
- c) The impact of *interference*, and hence forgetting, may be reduced by increasing the time between the arrival of inputs to be held in working memory and by reducing the similarity between items.
- d) *Rehearsal*: research shows that the more the information to be committed to memory is read and reviewed, the more likely it is to be retained.
- e) *Regular reviews* of those aspects of training which are not put into practice on a regular basis.
- f) Memory techniques (known as *mnemonics*) can be used to improve the retention of information (eg remember a list by using an easily remembered word, phrase or rhyme whose first letters are associated with the list items).
- g) *Demonstrations* by a minder driver or driver instructor can 'bring to life' or operationalise those areas with which the driver has difficulties.
- h) *One-to-one sessions* with experienced drivers provide the opportunity to explore suggestions for remembering particular signal sequences and routes.
- i) Review and modify current simulation, training and assessment exercises to integrate above strategies and lessons learned.
- j) Ensure delivery and content of training material matches the cognitive capabilities and needs of the target audience.

3.4.2 Long term (stored) memory

Information from working memory is transferred to *long term memory* by applying *meaning* to the information, and relating it to information already stored. For example, new temporary working instructions or procedures could be related to existing memorised procedures, and the differences between the two memorised.

The information in stored memory (ie existing procedures) is recalled with comparison and in relation to new knowledge (ie temporary procedures). So, to recall temporary working procedures, reference would be made to the stored usual procedures.

In such cases, there is the potential for error, in that the stored usual working procedures may interfere with the recall of the temporary procedures. For example, it may be difficult to distinguish between the stored and temporary procedures, especially when a driver is under additional pressures, such as time.

Examples of the use of stored memory are procedures, rules and route knowledge.

As well as storing the meaning we apply to the things we are able to do, long term memory also includes our knowledge about specific events, for example, a particular incident. The important point

to note here is that the information stored will not remain static, but will be influenced by our need to make sense of our experience and our expectations of what should have happened. Recollection of such events are, therefore, influenced by our *expectations* of the world. This tendency for us to remember what should have been, rather than what was, is a particular issue for accident investigators.

3.5 Decision making

Once information has been perceived, a decision must be made about what should be done with it. It may be used to initiate an immediate response, or be entered into part of the memory system (see above). For example, on hearing a warning sound, an operator may switch off the system, in which case the decision will involve the selection of a response. Alternatively, the operator may decide to hold the information in working memory whilst a search is made for the problem that triggered the alarm.

Decision making involves the close interplay between working memory and long term memory, in that in order to make a decision, judgement, or form a strategy, a driver has to call on information or knowledge (eg the weight of the train, the locomotive's braking characteristics, track gradient, aspects of previous signals, etc). Drivers have to judge or project distances and speeds (to signals, platforms, and of their train), make decisions (such as when to brake, what speed to proceed at) and form strategies (such as how far ahead of a signal they need to brake given their train configuration).

The ability to initiate a correct and timely response will be influenced by many factors. These include:

- a) Skill level of the driver
- b) Task complexity
- c) Quality of information
- d) Quantity of information
- e) Previous experience, knowledge and training
- f) Competing information
- g) Workload
- h) Fatigue levels
- i) Stress levels
- j) Time pressures.

Good practice examples – managing decision making

- a) Drivers should be aware that it is of paramount importance to make the correct, rather than the fastest response.
- b) Rehearse moving through the routines of the day, most importantly, re-check signal aspect and perform system checks before moving away.
- c) Develop and practice a mental checklist of considerations before moving out of a station, away from a signal, etc.
- d) Drivers and colleagues should be aware/develop a habit of checking anxiety levels (eg are there signs of nervousness, anxiety, worry, agitation, or irritability? Is there more sweating than usual, more restlessness or emotion? Do they feel that their heart is racing?). If anxiety levels are high, action should be taken to reduce it by moving through the routines of the day in a calm and considered manner.
- e) Try to consider all options available before taking action. For example, if drivers are about to make a shunt move which they are not confident about, pause, and consider potential options (eg contact manager/signaller).
- f) Drivers should think about the logic behind the actions being carried out, eg braking procedures, whilst carrying out these procedures. They should question their own actions for appropriateness and effectiveness.
- g) Drivers should refer back to training material and feedback on performance from colleagues, on a regular basis to inform decisions.
- h) Use the STAR principle - 'Stop, Think, Act, Review' (used in the nuclear industry) to manage decision making.

3.6 Action

In order to initiate a response, a decision must be translated into a specific sequence of conscious actions, words, or both, unless the behaviour has become automatised. Such actions, or speech, are the execution of previously formed (and correct) decisions.

Drivers have to physically interact with in-cab equipment, and must routinely select objects in the external environment in order to perform actions. However, when performing these actions there is the potential for *error* if there is a failure at the attentional level. For example, a driver may make an action *slip* if the wrong control is selected due to two controls being placed in close proximity to each other.

In a situation where there is pressure to make a rapid response, several factors must be borne in mind, since there will frequently be a trade-off between the need for speed and accuracy:

- a) In certain situations, where any delay can have catastrophic consequences, there will be pressure to make a response before sufficient information has been processed
- b) Conditions that increase arousal levels will lead to faster, but less accurate responding
- c) Since auditory stimuli are more likely to attract attention, than visual stimuli, they are more likely to be responded to in error
- d) If we expect a stimulus and prepare the appropriate response, we will respond more rapidly if the expected stimulus occurs; however, if an unexpected stimulus occurs, we will be more likely, under pressure, to make the wrong prepared response
- e) As age increases between 20 and 60 years responding tends to become slower, but more accurate.

4. Concentration and attention – limiting factors

Using the task of train driving as the primary example, this section summarises the main cognitive and individual factors that can impair attention and concentration and increase the potential for error.

4.1 Visibility, perceptual and vigilance factors

Research has suggested a number of influences that will affect whether a driver's attention is focused at the right time. These can be categorised as visibility, perceptual and vigilance factors (see figures 9-14 below):

Signal OA3



Figure 9 Visibility factors: station furniture can obscure signals



Figure 10 Visibility factors – 'bleaching' on emerging from a tunnel can temporarily impair vision



Figure 11 Visibility factors: curved approach can limit sighting time



Figure 12 Perception factors: curved approach can give wrong signal illusion



Figure 13 Perception factors: dark/complex signal background can reduce visibility



Figure 14 Vigilance factors – passenger distraction

4.2 Mental workload/operational demand

This refers to both the amount of work and the nature of the tasks. Since our ability to process information is limited (see Part 3), this will have obvious implications for the level of performance we are able to achieve.

The relationship between workload and performance can be conceived in the form of an inverted 'U' curve (see Figure 15)

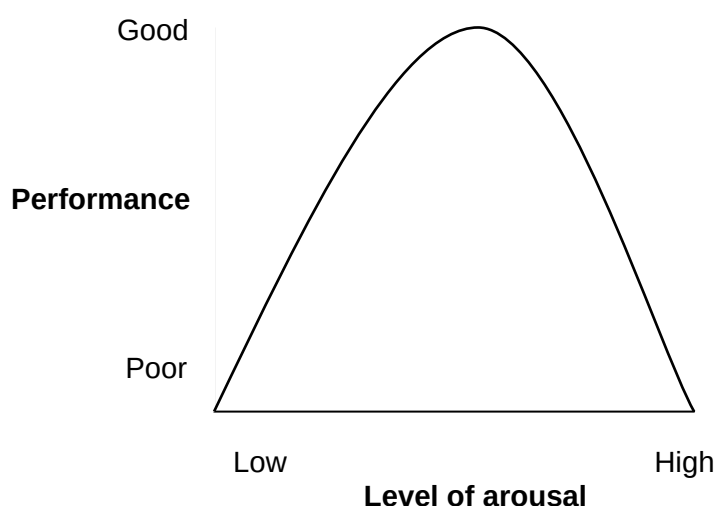


Figure 15 Relationship between workload and performance

Human performance at low levels of workload is not particularly good. Work under-load is where a job is routine, repetitive and under-stimulating. Under load also induces boredom, which may create lack of motivation and a loss of skills and can lead to errors with individuals being less alert and more prone to distraction.

Thus, at low levels of workload (underload) errors typically take the form of missed information due to individuals not taking in information from the environment around us.

As the demands of the task, or the workload is increased, the standard of our performance increases until an optimum level of workload and performance is achieved. Any increase in workload after this point will lead to a degradation in performance (eg too many tasks to complete in the available time, tasks are too similar and easily confused, conflict between the type of tasks required). At extremely high levels of workload (overload), important information may be missed due to the narrowing or focusing of attention on to only one aspect of the task.