Information, arousal and control in the UK railway industry: a focus group study.

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Abstract

This paper explores the results of a focus group study of Scottish train drivers in 2000. Results are studied in terms of arousal theory, especially the 'information-arousal' theory of D.E. Berlyne. This theory states that information can raise arousal and that operators will tend to attempt to attain their 'optimal arousal' point. Therefore if the information available to operators is too 'monotonous' they will attempt to seek out and gain different, 'arousing' information: in other words they will become bored and will seek out additional stimulus.

It was discovered that train drivers did indeed claim that driving similar routes and being in the same informational environment did lead to errors of concentration and error. It was also found that drivers claimed that they deliberately increased their risky behaviour (by, for example, 'chasing signals'), in order to mitigate boredom. It is shown how Berlyne's theories can account for these findings.

Finally the implications for ergonomics are discussed. It is proposed that drivers need to be in control of their information flow in order to maintain arousal and that, for example, the installation of devices on which music could be played might facilitate this.

Keywords: Boredom, Railways, Arousal, Risk Compensation, Information.

1. Introduction

Much work in psychology has been done on the concept of arousal, and it is consequently one of the best understood aspects of the human organism. The psychologist D.E. Berlyne was one of key developers of arousal theory, and although his theories have been criticised, they are still richly suggestive, and, as we will show, in some ways highly compatible with some other current paradigms in psychology, especially as these relate to systems theory and human factors. Moreover it may well be argued that the implications of arousal theory for these fields, whilst fairly well understood, are less often acted upon, and that the theory still has much to say as regards ergonomics and safety management.

Arousal is, in ordinary language, generally correlated with being 'excited', and is also associated with a range of biological features such as sweaty palms, pounding heart, perspiration and so on. While this is going on, a part of the brain called the Reticular Activating System (RAS) also becomes more active, thus producing feelings of being more 'awake' and 'alert' (Apter, 1992). In psychophysiological terms, an increase in arousal tends to be associated with an increase in MonoAmine Oxidase (MAO), a chemical, which, amongst other things, regulates the amounts of serotonin and dopamine in the brain. High levels of MAO tends to produce low arousal, whilst low levels of MAO tends to produce high arousal (Zuckerman, 1994). In other words, MAO functions as a thermostat, regulating bodily arousal levels, a concept to which we will return (Alverman, 1999).

Given that this is the case, and that, therefore, arousal is a basic feature of the human organism, it can be seen that organisms have an inbuilt urge to achieve what scientists, in a different context, call the 'Goldilocks' point: ('not too hot, not too cold'). This is illustrated by the 'Yerkes-Dodson' graph that correlates arousal (termed 'anxiety' in their theory) with performance (See Figure 1). That is, in the same we that we don't want to be too hungry or too full, or too hot or too cold, we have an inbuilt biological urge to achieve the right level of arousal (the 'optimum level') not too aroused or too under aroused: and our task performance improves when this point is reached. Being underaroused is usually associated, in ordinary language, with being 'bored'.

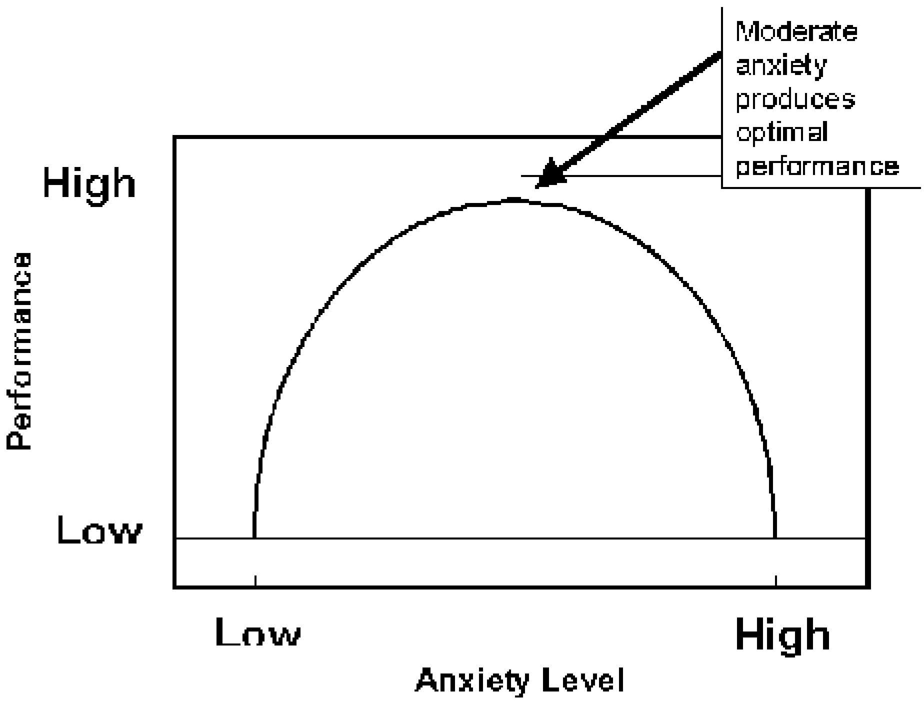

Figure 1. The Yerkes-Dodson Law.

Of course, things are not quite that simple in the real world. Firstly, the extent to which we wish to be aroused varies. In the morning, our internal arousal 'thermostat' is set at a low level, and so, for most of us, a cup of coffee and the radio in the background will suffice to help us achieve our optimal arousal level. Later on however, in the early evening, our arousal thermostat wishes us to be more aroused: and so we wish to go out, see a movie, go for a walk. In the same way, we wish to be under-aroused when we are trying to get to sleep. It's important to understand that, for example, in the evening, we need more arousal to attain our optimal point, even though in objective terms we may actually be more aroused than we were in the morning (in the same way that a thermostat may be set at 50 degrees in the morning and 70 degrees at night: in the morning the temperature may be 45 degrees and at night 60 degrees: this doesn't alter the fact that relative to the desired temperature the thermostat is further away from its desired point at night, even though the temperature is objectively higher) (Zuckerman, 1979).

Moreover, we sometimes need large amounts of arousal: a phenomenon termed 'the arousal jag' by Berlyne (1960). Think of people going on a roller coaster. However, for high levels of arousal 'what goes up must come down:' the enjoyable aspect of the experience is only really felt when the arousal stops, returning the organism to optimal again. A roller-coaster is fun for five minutes: if one were stuck on it for five days, we would feel rather differently about the matter. It should be noted that there is also some evidence that occasionally, moderate levels of arousal above optimal can be enjoyable in itself for reasonably long periods of time (going to see a movie for example) (Berlyne, 1971). Nevertheless arousal will tend to return to the optimal on average, over time (see below). The organism seeks, therefore, not homeostasis, but rheostasis: chasing an optimum level that changes over time (Cziko, 2000). There are also societal, age, gender and individual differences in arousal levels (Zuckerman, 1979).

Berlyne's innovation was to see that changes in information available to the organism changes arousal and that this can be quantified. It must be remembered that experiments on these behaviours have a slightly artificial aspect to them. In the real world, there is so much information available that it is impossible to 'control' other informational features. However, simple experiments can demonstrate the basic principles and we can then apply them by analogy to real world situations.

Berlyne began by demonstrating a link between arousal and the Orientation Reaction, (that is having one's attention drawn towards something), and then discovered links between arousal and the length for which something was viewed. He then performed various experiments that demonstrated links between various levels of arousal (i.e. how long something was looked at), and the amount of information in an object, described in bits, as specified in Shannon's information theory (Shannon, 1948).

This involved breaking down objects into discrete informational packages, and describing how much information was held in them in terms of 'bits'. For example a straight line would describe one bit. A triangle (where the lengths of the individual lines were the same as the original line) describes three bits. A square describes four bits. And so on.

In one experiment, for example, Berlyne exposed adult subjects to pairs of figures, each appearing for ten seconds, and measured how long they were looked at. It was found that more complex figures (i.e. figures that contained more information) were looked at for longer, and therefore, were more 'arousing' than simple figures. In a similar experiment, Berlyne showed that one other criterion was important (in rats and humans): 'surprisingness'. This can be defined in two ways. Firstly there is the more obvious definition: the way in which a piece of information differs from the last piece of information (for example, the difference between a triangle and a square). Secondly there is the rate of information flow. So for example if there is a long gap between one image on a computer screen and the next, the orientation reflex will 'kick in' even if it was the same as the last image. We know this in real life. If a loud noise is going on in the background all the time, we soon get used to it: but if it stops and then restarts after three minutes, we will 'get a shock' and 'be surprised' even though, in informational terms, it is the same stimulus (Berlyne, 1960). The corollary of this is that a constant flow of information will tend to be more arousing than an infrequent flow. If we went to see a movie which played at one frame per twenty minutes, it would be a good deal less arousing than one playing at the normal speed.

Therefore, information flow which is complex and surprising will maintain arousal. The corollary of this is that information flow which is simple and monotonous will lower arousal and cause a state of boredom. This is not a trivial point, in that the power of boredom is easily underestimated. In an experiment quoted in Vernon (1962) human subjects were kept in a 'completely homogenous and unvarying environment' that is, an information free environment (Vernon, 1962: 170). Most subjects suffered from extreme boredom and restlessness, deteriorating IQ and even hallucinations. Few were able to stand the experiment for more than two days, despite being extremely well paid.

A final point should be made. In later experiments Berlyne discovered that when asked what people liked or disliked, in the same way that they disliked oversimple, boring shapes, they also disliked overcomplex over'surprising' shapes. Therefore, they were attempting to reach their 'optimal level'. Over stimulation leads to anxiety. Under stimulation leads to boredom.

2. Discussion of Arousal Theory.

Before continuing to discuss the implications of this theory for ergonomics a number of issues should be discussed. Firstly, although in information terms we have used the language of discrete 'bits' to quantify (digital) information, it is highly likely that in a 'real world' situation humans perceive information in an analogue fashion. That is, people see things as being more or less complex or surprising, not complex/not complex or surprising/not surprising, and that, therefore, the language of 'fuzzy logic' is more appropriate than the 'digital' language used by Berlyne ('fits' not 'bits') (Kosko, 1994). However, this does not alter the basic thrust of the theory and will not be further discussed.

Secondly, and more importantly, as mentioned above, the chase for arousal is an example of the brain acting as a thermostat (as discussed by Ashby 1960). Therefore operators should be conceptualised not as passively being forced to be aroused or not aroused, but as actively seeking out rheostasis, the ever-changing arousal point. The 'arousal thermostat' is set at a certain point, and operators will seek information to reach rheostasis. Information is gathered (feedback), which alters their 'system', and the altered system will then seek out more information or less, on this basis. Operators are part of the system: permanently and actively part of a feedback ('cybernetic') loop (Flach, 2000). However, not only is this arousal point constantly changing (not just in terms of rheostasis, but also in terms of 'the arousal jag' and the other confines discussed above), but the nature of the information flow also tends to mitigate against keeping to 'optimum'. For the catch 22 is that when one has reached the ideal kind of mixture of complexity and surprisingness it instantly changes, because the same kind of information becomes boring. The incoming information must be dynamic.

Say, one is in an art gallery, and sees painting one likes. The Orientating Reaction (Berlyne, 1960) means we look at it, and then we continue to look at it. However, after a while, the same information, at the same rate (i.e. constant) tends to lead to lower arousal: and we become bored. So we go off and look at another painting and then the process repeats. So therefore, only constantly varied information can keep us at the optimum level, but because only we can say how arousing information is (because only we can compare it with previously experienced information), only we can decide what information, and how much, will keep us at the optimum. Therefore we need to have control of the situation to prevent boredom. We do not passively receive information, we actively go out and seek it: and not just any information but the kind we need to sustain or lower our arousal. In the morning we may only be able to cope with light classical music, in the evening we may wish to go to a nightclub, with its sensory overload. In the same way, if we find a task tedious, we will attempt to introduce new information by manipulating the environment, hereby actively altering our arousal levels. There are obvious links here with the theories of J.J. Gibson, who also posited humans as active, information seeking organisms (see Gibson, 1979). There are also obvious links with the theories of John Adams (1995), who has posited human beings as possessing a 'risk thermostat', which must be adjusted to maintain adequate levels of arousal. Human beings seeking risk and human beings seeking information may seem to be different hypotheses but as we shall see there are links between the two theories (see also Zuckerman 1979 for links between arousal levels and risk taking).

3. The Research.

Human Factors Analysts Ltd. (a private company associated with the University of Strathclyde) carried out a research project for Scotrail UK. It was proposed to divide drivers into two focus groups (drivers who had had SPADs (Signals Passed At Danger) and those who had not) to test the hypothesis that these two groups would produce different 'causal attributions' as to why drivers had SPADs (for more details of 'attribution theory' see Davies, 1997 and Antaki, 1988). In the course of these focus groups, data was also gathered about arousal and boredom: specifically about the way that drivers manipulated their information flow in order to maintain their arousal levels. (Note: the references that follow are from the 'raw' unpublished transcriptions of focus groups. For final report, see Wright, L., Ross, A., Davies, J.B., 2000.).

4. Findings of the focus groups.

When asked what causes SPADs the drivers all emphasised fatigue (caused by long shifts) and boredom (for links between boredom and fatigue see Mackworth, 1969). For example one driver commented:

"The hours that we work, long hours…boredom, repetition."

And continued:

"Aye, you get into autopilot, and you just drive away…and it's just, you know, every day's the same, it's no', you know, it's just the same run with the same things and it's boredom, boredom sets in then eventually you end up making, you end up with a mistake." (Focus Group 2, p1).

(This point is backed up by previous experimental work: c.f. McBain, 1970). However, (and this is the crucial point), instead of simple passively accepting this, drivers stated that they attempted to manipulate the information flow in order to increase their arousal. So, for example, drivers ended up daydreaming, playing games (such as, literally, counting sheep), 'chasing signals' (keeping a high speed when approaching a red signal in the expectation that it will turn green: the risk factor that they might be wrong heightening arousal. Of course this is a rule violation), or even singing in the cab!

"R1: You feel isolated, very very isolated.

R2: Especially see if you're a person that likes to talk […]

R1: It is you end up singing! Sing a different song! It's monotonous." (Focus groups Two: pp 16-17). (Note: "R" stands for Reporter).

This finding has again been found in other studies of boredom: operators attempt to manipulate their information flow to maintain arousal (O'Hanlon, 1981 and Fisher, 1993).

The corollary of this boredom is that when drivers start driving they feel they are given insufficient training and therefore become stressed (over aroused).

R1: I think that the kind of training we got, that was totally inadequate to be honest with you.'

R2: 'We didnae really get long enough. (Focus Group 2: p18).

R2: Unofficially it's been well known throughout the system that […] shocks, you know, you get a shock whenever you're going like, and you end up with this experience….nowadays kids just get chucked in at the deep end basically."

R2: It's just pressure at the end of the day, it's the pressure once they take that set away….it could be a hundred and million daft things, you know when you're panicking, it could be a simple thing, but that's the thing that you miss, you know, because you're worrying about everything else, and you're panicking, you know. (Focus Group 2, p21).

This, therefore, is stress resulting from information overload.

5. Discussion and Theory.

It should be stressed that much work has been done on the relationship between stress, boredom and arousal. Moreover, much work has also been done on the relationship between information and arousal. However, the key concept that has, perhaps, been under-emphasised in previous studies, is that the brain, in this respect at least, functions as a thermostat, regulating the body and the external environment in order to achieve the desired level of arousal. This is where the theory propounded here fits in with the concept of the risk thermostat as discussed by Adams (Adams, 1995). According to the focus groups, when drivers are bored (under aroused) they will manipulate the environment in order to raise their arousal. Increasing the information level available to them can do this, but of course, another key way of increasing arousal is to increase one's risky behaviour (producing the 'flight or fight' mechanism). This is not an either/or situation, since everything can be conceptualised as information. However it is clear that drivers who sing, day dream, 'chase signals' etc. are attempting to raise their arousal level and that when drivers state:

"R2: I think they should have some chill-out rooms in every depot, a little bit of

R1: Unwinding

R2: Background music, dim lights, and all this like." (Focus Group 2, p23).

What they are asking is for the opportunity to be able to lower their arousal when they are over aroused (stressed). Therefore, drivers ask for control over their arousal level.

This concept of control (which is crucial to systems theory and theories of rheostasis) may be of help when attempting to gauge when arousal is pleasant or unpleasant. When people feel themselves to be in control of the situation they can tolerate higher levels of arousal: because they are controlling the situation themselves (Gross, McIlveen,, Coolican, Clamp, & Russell, 2000). Stressful situations, on the other hand, tend to follow when the driver feels he has no control of the situation: in other words, he cannot lower (or raise) his arousal level himself.

6. The implications for ergonomics.

Many ergonomics manuals tend to assume that human beings are fundamentally passive. In this respect, there is no fundamental difference between the behaviourists (with this stimulus-response theories) and 'cognitivist' (stimulus-cognition-response) theories of action. However, what must be stressed is that the most up to date theories of human cognition stress the teleological, control driven aspect of human behaviour. This is particularly of importance in terms of man-machine relationships. We argue here, that whereas if drivers are in control of the information available to them they can regulate their own arousal levels, if they cannot do this, this leads to stress or boredom, both of which, as the drivers acknowledge, can lead to mistakes, and, therefore, accidents.

Therefore emphasis should be given to strengthening and increasing the amount of control drivers have over their arousal/information levels.

So drivers suggest:

R2: You get repetition because of the nature of the job, that's the same as a pilot…

R1: He's got a co-pilot though hasn't he?

R2: I do think we should have cabin crews coming in and out all the time.

R1: I do think maybe they should have some kind of radio, I think to relieve the boredom I think, cause it's really mentally tough - going on your own for 10 hours, and I think-

R2: A radio, I mean it's not just […]

R1: But I really think they should look into something about that, you know, the boredom factor, do something to take it away. […]

R2: The bus drivers have been doing it for years, driving about with the radio on.

(Focus Group 2: p 28).

The idea that drivers should have co-drivers, and a radio which they can control to modulate their arousal levels, echoes a very important point made by James Reason:

When background stimulation is low and signals few and far between, the level of arousal - and with it vigilance - begins to decline because the quantity and variety of the sensory inputs reaching the reticular formation are insufficient for it to carry out its job of maintaining cortical efficiency. […] Interestingly enough, many of these antidotes to vigilance decrement were unwittingly present on the footplate of the old steam locomotive. In between shovelling coal, the fireman would sit opposite the driver and help him with the identification of signals, train speeds and other problems connected with driving the engine. […] it is obvious that this system carries with it at least two advantages. Firstly, it kept the driver alert through the additional auditory stimulation and the presence of someone else in the cab. Secondly it provided the driver with confirmation of any unexpected signal. […] unfortunately the advent of the diesel engine broke up this happy partnership […] many trains began running with only one man in the cab.

(Reason, 1974: 148-149).

7. Conclusion

There are three main conclusions of this study.

1: Much of the development of automation has had the effect of removing control from the operator, in favour of computer systems and 'failsafe' mechanisms. The results of this study would question this approach. Instead, we argue that in order to regulate arousal (and, therefore, increase vigilance) the driver should have the maximum amount of control over his environment: specifically as regards information. This suggestion is borne out by current research on air traffic controllers (Metzger and Parasuraman, 2001). It is interesting in this respect that a Swedish study of railway cab conditions stated that 'not enough information (is currently) provided to the driver' and that when information is made available it should be 'dynamic information' (Lecklund, Ingre, Kecklund, Söderström, Akerstedt, Lindberg, Jansson, Olsson, Sandblad, & Ålmqvist, 2001).

We suggest that research should study the effects of (for example) having a radio in the cab, and the effects that this has on vigilance. We would predict that it would have a positive effect and that if this was the case, the introduction of radios which could play music (as long as this remained under the control of the driver) may have a positive impact on vigilance and performance (See for example the positive impact varied music had on performance in the experiments in Mackworth, 1969: 153-155). Interestingly in a highly progressive Canadian project, which produced excellent results, part of the study introduced a 'Locomotive Cab Audio System' playing stimulating music on headphones for the use of drivers (Sherry, 2000).

2: Again, an effect of automation has been to reduce the amount of staff necessary for a task. We would again question whether this is the correct approach. As the quote from James Reason above indicates, having more than one member of staff present not only increases arousal (on boring tasks), but also can act as a 'back up' system if anything goes wrong: See Wiener (1985) for more details on this.

3: Finally to be done safely a job should be interesting. This is a greatly neglected topic in ergonomics (Fisher, 1993 and Smith, 1981). However, automation, by reducing the complexity of the task, may contribute to making it more boring, surely another 'irony of automation' (Bainbridge, 1987). As Rudisill writes in her survey of airline pilot's attitudes to automation: 'There was a general concern that automation may increase boredom, thereby indirectly decreasing safety.' (Rudisill, 1995: 3).

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