# The Application of Operational Haptics in Automotive Engineering

*a report by*
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Over the last few years, demands on motorists have increased dramatically. The overwhelming need for mobility and the continually growing number of cars on our roads have made traffic ever more complex. The driver must now focus most of his/her attention outside of the car, on keeping the vehicle stable and in the correct lane. At the same time, the continuing evolution of processors, memory chips and other electronic components has led to innovations such as navigation displays or human-machine interfaces, which have turned the vehicle into a multifunctional environment. From officials, there are already concerns about road safety, as the growing number of communication devices could be distracting to the driver.

Driving and monitoring the functions of a car have become considerably more complicated. Though new integrated operating concepts can reduce the strain on the driver to a certain degree, a look into the future shows us that there are even more new functions to come. In the context of ergonomics, they need to be analysed regarding their ease of operation and then adapted to the special needs of the driver so that he/she will not be distracted from the principal task of driving.

This leads to the question of how the demands on the driver's attention can be minimised, especially for secondary tasks, and the potential distractions while still providing feedback on the operating status of the car. Ergonomically speaking, the comfort and ease of operation have to be taken into account as well.

## Sensory Perception in the Car

As humans, we perceive our surroundings – either consciously or subconsciously – by means of the six senses. If these are analysed with regard to their relevance to driving, it becomes clear that not all of them are equally important. Some, namely the sense of smell and the sense of taste, are not required at all, because they have no connection to the mental processes and actions that are involved in driving (unless a smell signals a defect in the car). The sense of balance is solely responsible for keeping the car stable and controlling the longitudinal, lateral and vertical acceleration. That leaves three senses – sight, hearing and touch – that can be used to operate and monitor the car. The significance of the sense of sight is marked by two peculiar aspects. It is widely known that approximately 80% to 90% of all sensory input is received via the eyes. The drawback, however, is that the maximum intake has already been reached, especially in the context of a dynamically changing situation like traffic. The second peculiarity is especially useful for monitoring the car, as the eye is the only sensory organ that can provide long-term feedback, e.g. from a constantly burning indicator lamp.

Hearing, on the other hand, is not taxed as much. The remaining capacity for the parallel intake of information has been of increasing importance for the support of the more complex systems in a car, such as the voice command of navigational devices. Unfortunately, past experience has shown that drivers do not like to receive driving instruction from a voice-command system.

The sense of touch is another channel for sensory input with a great deal of free capacity. It is a common misconception that all that can be learned from touch is the surface quality. When developing controls, people tend to forget that it is possible to use the sense of touch for receiving feedback on the activation of a function. Considering that there has been very little scientific research in this field, it is clear that the sense of touch is not deemed particularly important. However, tactile feedback from the controls in a car can – if it is unambiguous, precise and comfortable – provide the driver with important information about the operational status of the vehicle. The distraction to the driver is kept to a minimum, which contributes to overall road safety.

Audi AG has been working for several years on deliberately shaping the haptic feel of the controls in terms of ergonomics. Audi's goal is not merely to minimise distractions but, more importantly, to create one unique feeling for all controls with the emphasis on comfort and quality. A switch or button that feels inexpensive, even if it is technically perfect and functions properly, will create a negative impression for the customer.

## Physiological Aspects

When dealing with operational haptics, many different aspects need to be considered – from the physiological and psychological to the technical and financial – which are important to development engineers. The physiological basics are determined by the structure of the human skin, equipped with a number of highly sensitive sensors that enable the perception of sensations such as pressure, cold, warmth and pain. This is what is termed 'surface sensitivity', which constitutes haptics in the classical sense. The physiological data that is gathered in this process provides qualitative criteria and measurable physical quantities, namely surface properties, surface topology and surface structure, with which the haptics of any given object can be described.

Other sensors in the musculature and the tendons provide additional data on the forces used and the position of the joints. This is the so-called 'deep sensitivity' and the criteria derived from it are: operating force, travel and direction. Together, surface sensitivity and deep sensitivity form the core of operational haptics. Other aspects that come into play include the size of the control elements, any free travel in the mounting and acoustics and many more.

## Psychological Aspects

What is considerably more difficult is the assessment and integration of the psychological aspect of haptics. The subjective perception and patterns of behaviour have a decisive influence when addressing the issue of how the customer experiences the quality of an operating process. As products of our environment, we have learned various patterns of behaviour and have developed certain expectations based on them. Although we do not actively remember the learning process, patterns are still stored in our subconscious and determine how we approach the things around us.

These processes do not register on our consciousness because, eventually, the operation itself is merely a means to an end. The attention of the operator focuses on the actual task and on fulfilling the task as efficiently as possible. It is the end, not the means, that counts. As long as the operating process conforms to individual expectations and mental patterns, information processing and the operation itself happen subconsciously. It is not until some deeply ingrained criteria fail to fit a memorised pattern of behaviour that perception and operation penetrate into our consciousness.

An operational process is comparatively complex – as the number of qualitative criteria mentioned above suggest. Moreover, research has shown that an ordinary operator would rarely have objective criteria for evaluation, which brings about the following conclusions:

- Operational haptics are – with certain reservations – only perceived subconsciously.
- Operational haptics are judged on a subjective basis.
- The physical quantities that can be measured objectively need to be assessed with respect to their subjective repercussions.

## Objective Criteria in Detail

The greatest difficulty was in finding a way of dealing with operational haptics in an objective manner. Audi has been able to solve this problem in recent years. A team of experts conducted a thorough analysis of numerous operational processes and thus established a catalogue of objective criteria for the evaluation of these processes. In this context, it is interesting to note that working in operational haptics does not require a special sensitivity of the fingertips. It all happens in the head, so that is where the sensitivity is required. The work of the Team for Operational Haptics over the past few years has led to a series of findings that provide a valuable source of help in the development of controls.

## Force and Travel

The main criteria in operational haptics are operational force and travel. Although this statement holds true for all operations, including those that are performed in everyday life, the situation in a car warrants special consideration. For example, pressing a radio station button with the arm almost fully extended whilst driving over an uneven road surface is far more challenging than performing the same action at home on a personal stereo. It has turned out that in a car an operational force of 5 newtons (N) to 6N and an operational travel of 0.7mm to 1.0mm feels comfortable as well as being conducive to the confidence of operation.

## Characteristics

Even more important than the two separate criteria of force and travel is the interaction between them, which, to a great extent, determines the characteristics of a control element. In our experience, a linear connection conveys the impression of comfort and high quality (see *Figure 1*). A sagging (concave) curve before the switching point is felt to be imprecise, whereas an inflated (convex) curve suggests sluggishness or reluctance (see *Figure 2*).

The prerequisite for a tactile feedback is an event that can be perceived by the sensors in the skin or the

*Figure 1: Linear Characteristic*

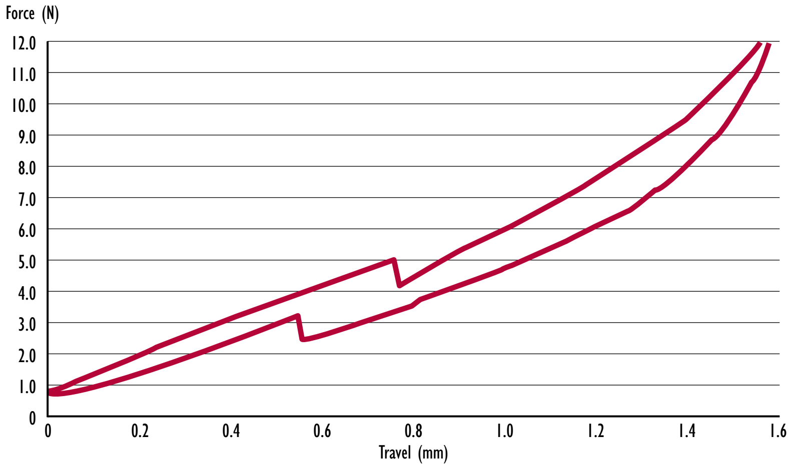
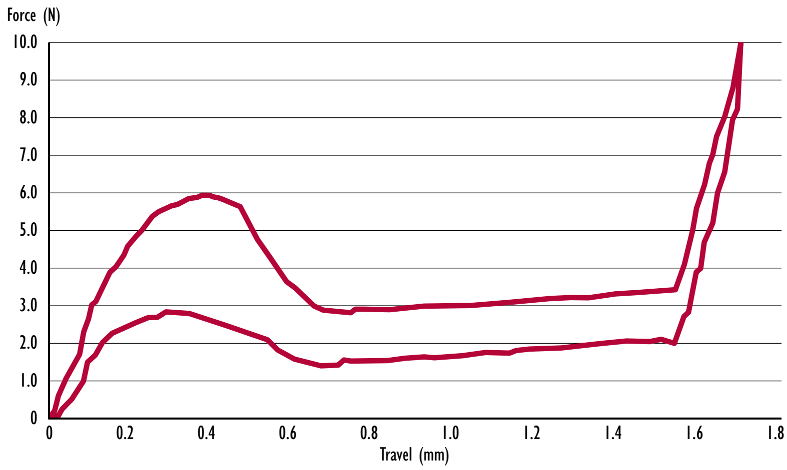



*Figure 2: Convex Characteristic*




muscles. Usually, passive control elements work with a drop in the force over the operational travel (see *Figure 1*). Important criteria for the layout are the gradient of the curve at this point and the extent of the drop in force. As a general rule, the lower the gradient of the curve the higher $\Delta F$ has to be. The layout at Audi is usually -50N/mm at approximately 0.8N. This precludes the use of conductive silicone switch pads, as they cannot achieve either the required force or the falling gradient of the force curve.

## Ease of Operation

So far, only those operational characteristics that are at best suitable for creating a distinct tactile feedback have been discussed, but these are not the characteristics that determine the ease of operation. Of major significance is the further development of the force/travel characteristic. Studies of operational habits have demonstrated, for example, that most people press a button up to 70% of the distance past the point of tactile feedback. If the model reaches its mechanical end-stop before that point, the button feels uncomfortably resistant. If the point of activation does not lie within the individual displacement – with regard to the individual customer – the corresponding component will be reported as faulty although, technically speaking, that is not the case. This leads to the following conclusions:

- Simple domes cannot create reliable feedback, as the switching point coincides with the end-stop. Besides, their distance of operational travel is too short, which is detrimental to the reliance of the operation.
- After passing the point of tactile feedback, the finger, for instance, has to be cushioned softly and gradually.
- The function must be activated precisely at the point of tactile feedback.

## Peculiarities in Operational Behaviour

A close observation of operational behaviour often reveals interesting peculiarities. From experience, it is known, for instance, that individuals perform an operation twice in quick succession when the operational force and travel are less than expected – i.e. they switch on an apparatus and switch it off again a split second later, much like a reflex. On the other hand, many drivers did not use the kick-down switch for long periods of time because they interpreted the high switching threshold as the mechanical end-stop. This was another result of a conflict between customers' expectations and the actual performance of a control element.

## Outlook

In the near future the automotive industry will have to devote more attention to operational haptics than it has so far. The active control elements that have recently arrived on the market under the heading 'forced feedback' (i.e. the haptic feel can be adjusted by software) are still a long way from creating a comfortable and high-quality feedback. Our expectations regarding the controls in a car are very different from those of a games console.

With the introduction of further x-by-wire technology, all of the concerned control elements are going to lose their familiar tactile characteristics, which will then have to be artificially generated. The electronic accelerator is quite a simple example of the possible applications of this new technology. Its introduction into gear shifting, steering or even braking will be far more challenging. The benefits of technological innovations need to be balanced with the ease of operation, the manageability and the learned handling of control elements. Even a technological revolution must not be more than an evolution for mankind, but a challenge for future development engineers. ■