NEW VOICES

The curious case of Sherlock Holmes and perceptual load

David James Robertson on an intriguing modern detective story, in the latest in our series for new writers (see www.bps.org.uk/newvoices)

> It is of the highest importance in the art of detection to be able to recognise, out of a number of facts, which are incidental and which are vital. Otherwise your energy and attention must be dissipated instead of being concentrated (Conan Doyle, 1894/2001, p.391.)

The preceding quote is elegant enough to have been written by William James in *The Principles of Psychology* (1890) as an explanation of our essential cognitive ability to focus our attention on relevant goal-directed information, while ignoring irrelevant and potentially distracting noise. Yet it is actually a description of the deductive processes of that most extraordinary of consulting detectives, Mr Sherlock Holmes. For Holmes, the ability to select only those relevant clues that are required to solve a case, while ignoring irrelevant and extraneous information that could cloud his reasoning, is an indispensible element of his expertise. Psychological research has made great progress over the last 60 years in understanding the cognitive and perceptual mechanisms that govern this essential selective process.

The extent to which we are able to ignore task-irrelevant information is the central investigative question examined in selective attention research. For example, what factors are involved in our ability to select and understand one relevant conversation, among extraneous chatter, in a crowded and noisy room (Cherry, 1953)? What mechanism provides us with the ability to assign focus and priority to the reading of this article, when there are other sources of potentially distracting visual information on this very page? Indeed, how the great Sherlock Holmes is instantly able to select the most relevant clues from a crime scene, while disregarding others which initially appear of high importance to his everyman sidekick Dr John Watson, is a testament to his extraordinary selective processes.

Sherlock Holmes – unclouded reasoning

The early vs. late debate

Initial explanations of these abilities were dominated by the 'early' vs. 'late' selection models of information processing (see Driver, 2001, for a review). Those in the 'early selection' camp (e.g. Broadbent, 1952), argued that our perception of relevant information was a limited-capacity process that required one to attend to an incoming stimulus in order for it to be perceived. In contrast, the 'late selection' view (e.g. Deutsch & Deutsch, 1963) argued that perception is an unlimited process that proceeds automatically with all incoming information (relevant or otherwise) undergoing full perceptual processing.

Like any good detective narrative in which the reader is periodically led to believe that one protagonist, or another, may be the chief suspect in a crime, empirical evidence was amassed that at one time favoured the 'early' selection approach over that of the 'late' and vice versa. However, the creation and development of the load theory of selective attention and cognitive control by Nilli Lavie (Lavie, 1995, 2005, 2010), has offered a resolution to this keenly contested debate.

Perceptual load theory

Load theory arose from an intriguing piece of modern scientific detective work, using the apparently contradictory evidence provided by the 'early' vs. 'late' selection theorists to provide a hybrid model of selective attention. It proposes that we have a finite amount of attentional resources with which to process incoming information (similar to the early selection view), while at the same time, perceptual processing proceeds automatically (as proposed in the late selection view) until all resources are fully utilised Therefore, the stage at which relevant information is selected for

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further processing – also termed 'the locus of selection' – is dependent on the level of perceptual load provided by the task in question. When perceptual load is high, and current task-relevant processing exhausts all perceptual capacity, task-irrelevant, distracting information is not perceived (early selection). Conversely, when perceptual load is low and current task-relevant information processing does not fully exhaust one's perceptual resources, the remaining resources 'spill over' to process task-irrelevant information and this results in the perception of distracting information (late selection).

Behavioural research

A wealth of data, using various experimental methodologies derived from psychological research and cognitive neuroscience, has provided strong empirical support for load theory (see Lavie, 2010, for a review). Several behavioural measures of distractor processing (task-irrelevant information) have been employed. One such measure is the 'letter search response competition' paradigm, in which subjects are required to detect a pre-specified target letter (e.g. X or N) from a letter-search array in the presence of a congruent (e.g. X when target is X) or incongruent (e.g. X when target is N) peripherally located distractor letter.

Results from studies using this paradigm consistently report that a distractor-congruency effect (indicating that the distractor letter has been processed and is interfering with which response to select) is found in low-perceptual-load displays (e.g. when the search target letter is presented alone), but not under high-load conditions (e.g. when the target needs to be found among similar non-target letters).

Several other illustrations of reduced distractor processing under high-perceptual-load conditions have also been reported. For example, Forster and Lavie (2008) reported elimination of distractor interference by high perceptual load in a study using colourful cartoon characters (e.g. Spiderman, Donald Duck) as irrelevant but meaningful attention-capturing distractors.

In an interesting extension of this work, Lavie et al. (2009) presented meaningful but irrelevant images of objects to participants in both high- and low-load conditions during a letter-search trial. Images were presented in the line of sight, not peripherally (see Figure 1). It was found that a significantly greater proportion of objects were recognised in a subsequent surprise recognition task if they had been presented in the low-load condition (recognition rates for objects presented in the high-load condition fell to chance level).

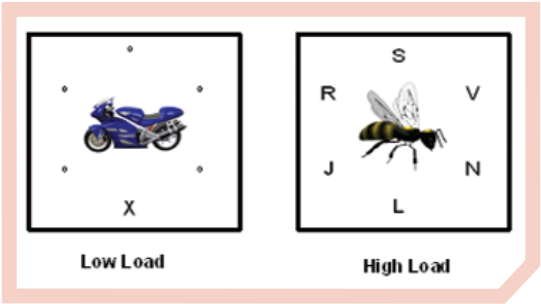

Figure 1: An example of a low- and high-perceptual-load letter-search array. Participants were instructed to locate a specified target letter (X or N) while ignoring task-irrelevant objects presented at the point at which subjects were instructed to fixate their gaze (Lavie et al., 2009).

More strikingly, this behavioural research has also been extended to the realm of internal distraction (mind wandering). Forster and Lavie (2009) found that mind wandering or task-unrelated thoughts were significantly reduced during tasks containing high perceptual load.

In another interesting twist, directly applicable to the work of Holmes and Watson, a study by Jenkins et al. (2004) reported that higher load led to chance level recognition for distractor faces that appeared in the background while subjects performed a selective attention task. In a similar vein, it has been found that people even fail to notice the presence of an additional visual or audio stimulus when it is presented during high (compared to low) load. This phenomenon has been termed inattentional blindness (Cartwright-Finch & Lavie, 2006) and inattentional deafness (MacDonald & Lavie, 2011) respectively. In the realm of the detective, these findings could cast doubt over the reliability of eyewitness testimony, identity parades and the utility of crime scene reconstructions, as in a crime scene situation the witness may have been overloaded with information and as a result not have processed an event that may be crucial to an investigation.

Taken together, this behavioural research depicts the elegant relationship at the heart of load theory; low perceptual load leads to greater processing of task-irrelevant distraction (e.g. peripheral letters, meaningful distractor images located peripherally and centrally, internal distraction) (late selection), while high perceptual load actually eliminates the perception of task-irrelevant information (early selection) as there are no spare attentional resources remaining with which to process irrelevant distraction.

Cognitive neuroscience approach

Evidence for load theory has also been found using experimental methods from cognitive neuroscience. In an fMRI study, Rees et al. (1997) reported that a peripheral-motion distractor produced significantly greater activation in motion-sensitive cortices (e.g. MT/V5) during a low-load, in comparison to a high-load,

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task. Brain activation responses related to other types of distracting stimuli, such as emotional face processing, have also been found to be dependent on the particular level of perceptual load of the primary task (e.g. Bishop et al., 2007).

Clinical research

Load theory has also been applied in clinical research to a number of conditions including anxiety, schizophrenia and congenital deafness. In one such example, Remington et al. (2009) hypothesised that autism spectrum disorder involves an enhancement of perceptual capacity. They therefore tested whether adults with autism would require a higher level of perceptual load than controls in order to eliminate distractor processing. The results supported this prediction in favour of enhanced perceptual capacity in this condition. Conversely, other lines of research have shown situations in which lower levels of perceptual load are required to eliminate distractor processing; among the elderly (Maylor & Lavie, 1998), and patients with unilateral neglect (Lavie & Robertson, 2001).

Conclusions

So, what would the dynamic duo of Holmes and Watson have made of load theory? Like each of us, Watson has a limited amount of attentional resources. In a low-load situation such as relaxing at 221b Baker Street, Watson may be distracted by Holmes' violin playing. However, when surveying a murder scene and being overloaded with information, Watson may not have the remaining perceptual resources to pick up the additional, less salient, but nevertheless vital, clues that Holmes appears to encounter vividly.

However, Holmes' increased perceptual capacity must also be accompanied by an enhanced cognitive capacity that allows him more effectively to prioritise the importance of additional crime scene information that this enhanced capacity allows him to perceive (see Lavie et al., 2004, for recent developments on cognitive load that could further elucidate Holmes' remarkable deductive and selective powers).

Arthur Conan Doyle created a rich fabric of different adventures for Holmes to apply his great perceptual and cognitive abilities to. In a similar fashion, in the 17 years since Lavie introduced load theory, its central narrative has been applied to many different, new, and exiting areas of psychological research, only a sample of which are discussed in this article. It should be noted that although the level of perceptual load in a given task is regarded as a major determinant of the efficiency of selective attention, research has shown that there are other contributing factors, such as the type of distractors presented, their relative salience and the effects of spatial cuing on distractor processing (Eltiti et al., 2005; Lavie et al., 2003; Johnston et al., 2002).

Having been built on solid empirical research, load theory occupies a dominant position in current thinking on information processing and distraction. As an explanation of the mechanism of our ability to attend to relevant information, one might even venture so far as to say, 'It's elementary…dear reader.'

However, as any good scientist or consulting detective will tell you, further research is required to enhance our understanding of the remarkable mysteries of the human selective attention process.

Perhaps one might be better to say, 'The case continues…'

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