Selective attention and Load Theory

Audition was the domain of much of the initial research on selective attention. The analogy of a cocktail party posed many intriguing questions. Namely, amidst all the hubbub and background noise how does one attend to that which is relevant, and ignore the rest. What is the difference in processing between what is attended to and what is not, and how much knowledge of the unattended input does one retain (Deutsch & Deutsch, 1963). The selective shadowing task was thus developed; here a participant was presented with two differing messages in each ear, the participant attended to one message whilst ignoring the other and were required to repeat the attended message put loud as rapidly as possible. It was concluded that in order for efficient shadowing to occur, the messages must be clearly different in physical properties (location/ear) and have distinctly dissimilar voices. If these criteria are met participants tend to notice almost nothing of the non-shadowed message, although some subtler physical properties, such as drastic pitch change or the termination of a message, can be retrospectively reported on occasion (Driver, 2001).

Donald Broadbent (1958) was the first to postulate a model of selective attention. Drawing from evidence in shadowing tasks, his filter theory was an attempt to explain the differences that must necessarily exist between inputs for efficient selective attention, and to determine how much of the unattended input one is aware of (Driver, 2001). Broadbent outlined two successive stages responsible for processing incoming perceptual information. Firstly, the basic and physical properties of incoming stimuli are extracted in parallel, such as pitch or volume for sound. There is then a selective filter which funnels only the target perceptions into the second stage, this filter acts to prevent the second stage from overloading, as it has a limited capacity. In the second stage the psychological features are extracted serially, such as the meaning of a spoken word or sentence (Treisman, 1969). In vision this theory implies that we are only capable of identifying one object at a time (Lee & Choo, 2013).

The filter theory of selective attention has since been falsified as numerous studies have found evidence of participant's knowledge of unattended stimuli, which according to Broadbent (1958) should not have passed through the selective filter, nor should any meaningful psychological features of it be known. Treisman (1960) found that during shadowing tasks which presented separate inputs to each ear, but were designed to switch to the opposite ear unexpectedly during the experiment, participants would also switch to which ear they attended to, to continue repeating the target words. This switch would not be made if the unattended passage had not made it passed the filtering process as the necessary features for discriminating the target passage were psychological. Thus, filter theory fails to explain the more complex cases of attention, where many discriminations must be made (Deutsch & Deutsch, 1963). This model is an example of an 'early selection' approach to selective attention as attended and unattended stimuli are posited to be processed differently early on in perception (Driver, 2001).

To account for the discrepancies in findings which filter theory could not explain, 'late selection' theories of selective attention were developed. Unlike filter theory where incoming unnecessary stimuli are excluded from full perceptual processing, adherents to the late selection perspective posit that it is more likely that irrelevant or non-target information is included fully in perceptual processing, but excluded from entering memory and/ or influencing deliberate reactionary responses (Deutsch & Deutsch, 1963; Duncan, 1980). Thus, Broadbent's initial unlimited, parallel stage now can include all incoming perceptual information, with the second limited, serial stage now responsible for selection for awareness, memory and/or response (Driver, 2001). Visual stimuli for instance, are thus processed in multitudes of unselected objects, which then venture into the semantic filter without any limitation (Lee & Choo, 2013).

Treisman (1969) suggested a compromise between early and late selection models, in which unattended stimuli are not filtered out, rather they are attenuated into the second stage of processing. Thus, the second stage receives input form attended and unattended stimuli, but the signal is weaker for the latter, possibly so weak as to disable any possibility of extracting abstract/ psychological properties such as meaning. However, in some cases, the attenuated stimulus may be adequate for identification. Selective attention, in this model operates as a continuum rather than a fixed state, sliding between the two poles of immediate reflex and deliberate action (Lee & Choo, 2013). Evidence for this is found in Treisman's experiment (1960), and in similar shadowing tasks where the unattended ear presents the participant's name, as we are sufficiently primed to recognise our own name the signal is strong enough to seep into full attention (Moray, 1959). Conflict paradigms like the flanker task, suggest that both early and late stages affect response selection. They illustrate that response-incompatible information affect one's ability to respond quickly, which suggests that selectivity consists of two phases. In the first, selection is poor, and leads to fast but unreliable responses. Whereas in the second phase, selectivity is high, leading to reliable but slow responses (Hubner, Steinhauser & Lehle, 2010).

In vision, theories of selective attention attempt to outline the limits of our ability to see and subsequently report several things simultaneously (Duncan, 1984). The selection process can be divided into two theoretical approaches: space-based, and object-based selection. Space-based theories are best explained with metaphors such as attention working as a spotlight, or a zoom lens. In mental spotlight theory (Posner et al. 1980) attention is posited to focus on a particular area of visual space, stimuli within the boundary of this visual field receive full perceptual analysis (Duncan, 1984; Pinsk, Doniger & Kastner, 2004). Similarly, the zoom lens analogy posits that only objects within the attended area of visual space are processed fully. An object can be 'zoomed' in on to give its details a higher spatial resolution, or the area may be made larger but at the cost of decreased definition, thus it assumes that the position, size and form of the attentional filter are to a certain extent, variable. These changes are assumed to occur rapidly as opposed to continuously (Hubner et al. 2010; Treisman & Schmidt, 1982).

Conversely, object-based theories contend that a single object is perceived and processed fully, whilst neighbouring objects do not receive the same level of attention (Lee & Choo, 2013). Duncan (1984) conducted an experiment which used stimuli of various complexities, it was found that participants could more readily report features of the same objects, as opposed to, features of different objects located in the same area. Mishkin et al., (1983) suggest that the divergence in evidence backing space-based and object-based theories may be indicative of two distinct aspects of visual attention. They propose that as the type of task determines whether the 'where' or 'what' visual pathway will be used, it also determines whether stimuli will be processed objectively or spatially.

Feature integration theory (Treisman and Gelade 1980; Treisman and Schmidt, 1982) was specifically designed as an attempt to explain visual attention. It proposes that different features of visual stimuli such as colour, and orientation are processed in parallel 'preattentively', serial attention is then required for the location of each object in order to integrate these features. This theory was an attempt to solve the 'binding problem'; how the visual system constructs objects from all of their complex features (Lee & Choo, 2013). Evidence for this model was initially found in visual search paradigms, where the participant was asked to search for a certain target among several non-targets, and to determine its absence or presence as rapidly as possible. In cases of 'parallel' search tasks, the target would leap out of the display, so readily available for identification. No change in performance speed and efficiency was found to be resultant for fewer or greater numbers of non-targets, in other words the number of distractors did not affect the overall proficiency of participants to identify targets. In cases of 'serial' search tasks, the addition of non-targets makes the task substantially more difficult to complete. This effect can be quite linear, suggesting that a process had to be repeated each time for every single target and non-target (Driver, 2001).

The load theory of selective attention, as proposed by Lavie (1995) is a hybrid model which fully reconciles the 'early' and 'late' selection debate. In this model, a compromise is reached between the two approaches as the assumption that perception has a limited capacity is shared with the 'early' approach, whilst the assumption that perception is automatic is shared with the 'late' approach. The perceiver prioritizes the allocation of attentional resources on target stimuli, and irrelevant information is then excluded from processing provided that the relevant processing utilizes the entirety of the available capacity (Lavie & Tsal, 1994). If the task is undemanding or can be completed with relative ease, then the unused attentional capacity will be occupied by distractor information (Driver, 2001). In other words, this means that 'early' selection occurs in situations of high perceptual load, whilst situations of low perceptual load require 'late' selection processes (Lee & Choo, 2013).

Lavie (1995) posits that perceptual load is pivotal in successfully utilizing one's selective attention. Varying manipulations of load demonstrated that under conditions of high perceptual load on goal-directed tasks there is little to no interference from distractor information, however, under conditions of low perceptual load interference from irrelevant distractors is abundant. Thus, one's ability to ignore irrelevant information during goal-directed tasks is directly related to the type of perceptual load in the processing of the target information. Evidence for this can also be found in studies which show a decreased effect in flanker tasks in more highly loaded situations (Lavie, 1995). Conversely, high load on processes of cognitive control such as task coordination and working memory, increases distractor interference (Lavie, Hirst, De Fockert, & Viding, 2004). Cognitive control functions are highly loaded when one must attempt to actively maintain some aspect of unrelated material to the task at hand in working memory, or when people are required to continually switch between different tasks (Lavie, 2010). Cognitive control may thus be necessary for actively distinguishing between targets and distractors during processing (Lavie, 2005). Thus, both manipulations of perceptual or cognitive load increase general task difficulty, however they produce drastically opposite effects on interfering distractor information (Lavie et al. 2004).

Functional magnetic resonance imaging also illustrates this process of a load-dependent mechanism of selective attention in processing stages in the visual cortex (Pinsk et al. 2004). The opposite effects of perceptual, and cognitive control load illustrate the importance of considering the nature of the loaded mental processes in any given scenario. The fact that high cognitive load leads to increased distraction, and that high perceptual load causes the opposite also rules out general task difficulty to account for the effects of the two types of load (Lavie, 2010). Load theory suggests that the efficacy of selective attention to ignore irrelevant information hinges on two dissociable mechanisms. Firstly, a passive perceptual selection mechanism excludes distractor information from early perceptual processes when a task possesses a high perceptual load, thus preventing the exhaustion of the available capacity and allowing for the processing of solely relevant information. Secondly, an active cognitive control mechanism is responsible for orchestrating behaviour in accordance with the priorities of the task at hand. This function serves to minimize incoming distractor information from unnecessary stimuli, even in situations where these irrelevant stimuli may still be fully perceived, as is the case in tasks of low perceptual load (Lavie et al. 2004). As such load theory has contributed greatly to the field of selective attention by bridging the gap between the two seemingly polar-opposite approaches of 'early' and 'late' selection models and providing a cohesive and unified theoretical account which has garnered much support from several streams of psychological investigative research.

REFERENCES:

Broadbent, D. E. (1958). *Perception and Communication.* Oxford: Oxford University Press.

Deutsch, J. A., & Deutsch, D. (1963). Attention: Some theoretical considerations. *Psychological Review,* 87, 272-300.

Driver, J. (2001). A Selective Review of Selective Attention Research from the Past Century. *British Journal of Psychology,* 92, 53-78. DOI: 10.1348/000712601162103

Duncan, J. (1984). Selective Attention and the Organization of Visual Information. *Journal of Experimental Psychology: General,* 113, 501-517.

Hübner, R., Steinhauser, M. and Lehle, C. (2010). A dual-stage two-phase model of selective attention. *Psychological Review*, 117(3), 759-784. DOI:10.1037/a0019471

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *Journal Of Experimental Psychology: Human Perception And Performance*, *21*(3), 451-468. DOI:10.1037//0096-1523.21.3.451

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends in Cognitive Sciences*, *9*(2), 75-82. DOI:10.1016/j.tics.2004.12.004

Lavie, N., Hirst, A., de Fockert, J., & Viding, E. (2004). Load Theory of Selective Attention and Cognitive Control. *Journal Of Experimental Psychology: General*, *133*(3), 339-354. DOI:10.1037/0096-3445.133.3.339

Lavie, N., & Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Perception & Psychophysics*, *56*(2), 183-197. DOI: 10.3758/bf03213897

Lee, K. and Choo, H. (2011). A critical review of selective attention: an interdisciplinary perspective. *Artificial Intelligence Review*, 40(1), 27-50. DOI:10.1007/s10462-011-9278-y

Mishkin, M., Ungerleider, L. G., & Macko, K. A. (1983). Object vision and spatial vision: two cortical pathways. *Trends in Neuroscience*, 6, 414–417.

Moray, N. P. (1959). Attention in Dichotic Listening: Affective Cues and the influence of instructions. *Quarterly Journal of Experimental Psychology,* 11, 56-60.

Posner, M.I., Snyder, C. R. R., & Davidson, B. J. (1980). Attention and the detection of signals. *J Exp Psychol Gen,* 109, 160–174.

Treisman, A. (1960). Contextual Cues in Selective Listening. *Quarterly Journal of Experimental Psychology,* 12, 242-248. DOI: 10.1080/17470216008416732

Treisman, A. (1969). Strategies and Models of selective attention. *Psychological Review,* 76, 282-299. DOI: 10.1037/h0027242

Treisman, A., & Gelade, G. (1980). A Feature Integration Theory of Attention. *Cognitive Psychology,* 12, 97-136. DOI: 10.1016/0010-0285(80)90005-5

Treisman, A., & Schmidt, H. (1982). Illusory conjunctions in the perception of objects. *Cognitive Psychology,* 14, 107-141. DOI: 10.1016/0010-0285(82)90006-8