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Psychology: Revisiting the Classic Studies

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Attention: Beyond Cherry's (1953) cocktail party problem

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BACKGROUND TO THE CLASSIC STUDY

It is crucially important for psychologists to understand attention, as it is the starting point for all subsequent cognitive processing. So far as everyday life is concerned, we all spend much of our time engaged in selective attention, which involves choosing which of the myriad stimuli presented to our senses to attend to. This topic was recognised as being of major significance by the American psychologist William James (1890), who was right on that issue as on so many others.

Research on selective attention continued throughout the first half of the twentieth century. However, this research was limited in scope, as can be seen from a perusal of Woodworth's (1938) highly influential textbook on experimental psychology. He devoted only one chapter out of 30 to attention and considers topics such as the span of apprehension or attention span (the number of objects that can be assessed accurately after a brief presentation) and distractibility. Most of this research involved the visual modality and there was scarcely any mention of selective attention. Overall, it appeared that attention had not been the focus of much research in the almost half-century since William James emphasised its importance.

The dominance of behaviourism played a part in inhibiting researchers from exploring the topic of attention. Why was that the case? Basic behaviourism involved an emphasis on the need to be 'scientific', by which was meant a focus on observable stimuli and responses. The behaviourists had a problem with the concept of 'attention' because it was clearly neither a stimulus nor a response, coupled with the difficulty in measuring it with any precision. This may explain why researchers focused on simple tasks such as span of apprehension and decided not to explore the internal mechanisms underlying selective attention.

It was probably an advantage for Colin Cherry (1914–1979) that he had not trained as a psychologist and so was probably oblivious of the constraints that behaviourism imposed on psychological research. He had a range of professional interests, most of which were of a practical nature. He was a trained electronics

engineer and was involved in radar research during the Second World War. When he became a Professor at Imperial College London in 1958, his Chair was in Telecommunications.

There are some interesting parallels between Cherry's experience on the one hand and the early career of Donald Broadbent on the other hand. Broadbent also made substantial contributions to our understanding of selective attention in the 1950s (these contributions are discussed more fully later). Much of Broadbent's interest in attention arose from considering the difficulties that radar operators had during the Second World War in communicating with several pilots at the same time. These difficulties were compounded because the pilots' voices were all heard over the same loudspeaker (Driver, 2001).

Around 1950, Colin Cherry became interested in what is generally known as the 'cocktail party problem' (a phrase that he himself came up with). Suppose you find yourself at a cocktail party (such parties are sadly less common now than in the past) with many people talking loudly at the same time. What is striking (and in some ways surprising) is that it is often possible for individuals to 'tune into' one person's voice and more or less ignore other people's. It is tempting to think that one reason why Cherry decided to focus on such a 'real world' problem was because his background was in solving such problems rather than being confined to the artificiality of the experimental laboratory.

DETAILED DESCRIPTION OF THE CLASSIC STUDY

Colin Cherry decided to investigate the cocktail party problem. This is a more complex and important problem than you might imagine. We can see its complexity in the finding that experts have found it extremely difficult to devise automatic speech recognition systems that can successfully separate out one voice from several concurrent voices (Shen, Olive, & Jones, 2008).

Cherry reported the findings of his initial experiments on this problem in his classic study (Cherry, 1953). His research was relatively straightforward. However, it was hugely important because he was addressing fundamental issues. First, what are the differences between two concurrent auditory messages that are used by listeners to select one and ignore the other? Second, what information do listeners typically extract from the message to which they are not attending?

Cherry (1953) started by presenting two messages recorded by the same speaker on one tape so that both ears received precisely the same input. The participant was instructed to repeat one of the messages (i.e., to shadow it) while ignoring the other simultaneous message and he was permitted to play the tape as often as necessary to perform the task. The most striking finding of this experiment was that the participant found it incredibly difficult to perform the task, and would often shut his eyes to enhance his concentration. Some phrases had to be listened to up to 20 times before he identified them correctly. Some errors were made (no precise numbers are provided!), most of which were words that had a reasonably high probability within the context of the message. Thus, top-down processes played a role.

In the next experiment, Cherry (1953) made it even harder for the listener to discriminate between the two auditory messages. What was done was to present two concurrent auditory messages in the same voice to both ears with each message consisting of a string of unrelated clichés (e.g., 'I am happy to be here today'; 'We are on the brink of ruin'). The listener typically produced complete clichés in what he said; the problem was that he produced comparable numbers of clichés from each message and so showed no ability to distinguish between the two messages. The reason why performance was even worse in this experiment than the previous one was that there were no thematic differences between the two messages. This meant that the listener could not use top-down processes based on knowledge of the theme of the attended message to facilitate selective auditory attention.

Cherry (1953) then moved on to a series of experiments in which two auditory messages in the same voice were presented concurrently. Now, however, one message was presented only to the left ear and the other message only to the right ear. Again, the listener had to repeat back or shadow one of the messages. This is the dichotic listening task and it has been used extensively ever since.

Cherry (1953) was impressed by the substantial differences in the listener's performance by this apparently modest change in what was presented to him. In his own words, 'The subject experiences no difficulty in listening to either speech at will and "rejecting" the unwanted one' (p. 977). However, Cherry was most impressed by the other main finding that emerged from this experiment: 'If the subject is subsequently asked to repeat anything of what he heard in his other (rejected-message) ear, he can say little about it at all' (p. 978).

This last finding prompted Cherry to carry out further experiments in which two auditory messages were presented, one to each ear, with instructions to repeat or shadow the one presented to the right ear. In one experiment, normal male-spoken English was presented on the unattended message, as in previous research. Cherry found that listeners did not realise when the unattended message was in German. Reversed speech was either identified as normal speech or as speech having something odd about it. Listeners in all of these experiments failed to identify any word or phrase presented in the unattended message.

The listeners' performance was better in other experiments. For example, they nearly always identified when the unattended message was in a female voice (the attended message was in a male voice). In addition, they always detected when a 400 cycles per second pure tone was presented on the unattended message.

The overall pattern of findings obtained by Cherry (1953) seemed reasonably clear-cut. Listeners were very effective at using physical differences between the two messages to repeat back or shadow one message. They were remarkably poor at detecting words in the unattended message but were very good at detecting major physical differences between the unattended and attended messages.

A complication arose in another of Cherry's experiments. Listeners were instructed to repeat back or shadow the message presented in a male voice to their right ear. Unknown to them, the identical message was also presented to the left ear at a variable delay to the same message presented to the right ear. Nearly all

the participants detected at some point that the message on the unattended ear was the same as that on the attended ear. The time delay of the unattended message compared to the attended message at which detection occurred was typically between two and six seconds. This finding is surprising in that listeners in the previous experiments never identified any words at all in the unattended message. It suggests that there is continuing activation of words presented in the attended message which facilitates their subsequent detection in the unattended message.

There is a final point that needs to be made about Cherry's study. It is very strong in terms of its empirical contribution to selective attention. However, what is perhaps surprising is that Cherry had relatively little to say at a theoretical level. For example, consider the role of top-down processes based on expectations and predictions. Cherry was well aware that some of his findings (e.g., errors involving words highly probable in context; clichés produced rapidly in their entirety) indicated that top-down processes had a role in selective auditory attention. However, he failed to address important theoretical issues, such as the ways in which bottom-up and top-down processes interact to determine what the listener hears.

IMPACT OF THE CLASSIC STUDY

Cherry's (1953) classic study has had an enormous impact. According to Google Scholar, this article has been cited over 2,700 times, which is an exceptionally high figure. I also used *Web of Science* to see the number of citations for the topic of the cocktail party problem. The mean number of citations per annum has been between 350 and 400 in recent years – very few research topics attract that level of interest well over 50 years after their publication.

Cherry's research had a strong influence on the theorising of the British psychologist Donald Broadbent, who was one of the pivotal figures (possibly the *most* pivotal) in the rise of cognitive psychology. As we will see, his filter theory (proposed in the late 1950s), was built squarely on Cherry's findings. Remember that Cherry found that selective attention to one out of two concurrent auditory messages was most efficient when there were clear physical differences between them (e.g., pitch, apparent source). His other major finding was that listeners apparently noticed only simple physical features (e.g., pitch) of the ignored message.

Broadbent's (1958) filter theory incorporated the important insight that the above two findings are related (Driver, 2001). In essence, he argued that two major stages are involved in perception. First, the physical properties of auditory stimuli (e.g., pitch, sound location) are extracted in parallel for all stimuli. Second, the more 'abstract' properties of auditory stimuli (e.g., their meaning) are processed in a serial fashion. The second stage has limited capacity, and so there is a filter which allows only stimuli possessing a given physical property to enter.

It would be difficult to overestimate the influence that Broadbent's filter theory has had. Here are just a few examples. First, Broadbent's theory was one of the earliest attempts to develop an information-processing approach in which there

are several successive processing stages. That notion became hugely influential in the following decades and remains so (Eysenck & Keane, 2010).

Second, the limited capacity that Broadbent associated with the second stage of processing overlaps with notions of the limited capacity of short-term memory and the limits of central processing units in computers. Attempts to assess the limited capacity of short-term memory were made during the 1950s. The most famous of such attempts was by Miller (1956), who referred to 'the magic number seven, plus or minus two'.

Third, as Driver (2001) pointed out, numerous subsequent cognitive theorists followed Broadbent in arguing that an initial parallel 'pre-attentive' stage of processing is followed by a serial 'attentive' stage. This is especially clear with respect to research on consciousness. According to global workspace theory (Baars, 1997), initial processing of stimuli involves numerous special-purpose unconscious processors operating in parallel. After that, conscious experience is associated with integrated or synchronous brain activity across several different brain areas. There is much support for this theoretical position (e.g., Melloni, Molina, Pena, Torres, Singer, & Rodriguez, 2007).

We have seen that there is a very direct historical trail from Cherry to Broadbent. The same is true if we consider Broadbent and Treisman. Anne Treisman was one of Broadbent's PhD students, and she went on to make several outstanding theoretical contributions to our understanding of selective attention. Of particular relevance here, Treisman's (1964) attenuation theory represented a revision and extension of Broadbent's filter theory.

It is an interesting historical curiosity that research on selective attention in the 1950s was predominantly on auditory attention whereas ever since it has mostly been on visual attention. Of course, the dominance of auditory attention in the 1950s owed a substantial amount to Cherry's research. The switch to research on visual attention occurred in part because it is easier to exert precise experimental control over visual stimuli than auditory ones (e.g., in terms of exact timing). It also occurred because for most humans vision is the dominant sense.

Cherry's research and Broadbent's theorising had a strong impact on visual attention research in the 1960s. For example, consider research using the Sperling paradigm (Sperling, 1960). Several letters (e.g., four rows of three letters) are presented in an array, followed by full or partial report. Full report requires participants to report all the letters in the array, whereas partial report involves presentation of a cue, indicating that only a subset of the letters (e.g., the bottom row) has to be reported. Participants typically perform better in the latter condition than the former one, suggesting that the rapid decay of information about the letters in the array impairs performance in the former condition. Of most relevance with respect to Cherry's research, selective report is generally better when relevant and irrelevant letters differ in terms of some physical property (e.g., colour) than when they differ in a more abstract property (e.g., digit versus letter) (Von Wright, 1970). This finding clearly resembles the findings Cherry obtained with auditory stimuli.

One of the most striking findings reported by Cherry (1953) was that selective auditory attention can be extremely efficient. It was only many years later that cognitive neuroscientists began to uncover evidence of brain mechanisms associated with this high level of efficiency. Much of what happens within the auditory system is a 'winner-takes-all' situation in which the processing of the attended auditory input (the winner) suppresses the brain activity of the other auditory input or inputs (Kurt, Deutscher, Crook, Ohl, Budinger, Moeller, et al., 2008). This was shown clearly by Horton, D'Zmura, and Srinivasan (2013) in a study in which listeners were instructed to attend to the auditory message on one ear and to ignore the message presented to the other ear. There was enhanced brain activity associated with the attended message combined with reduced or suppressed activity associated with the unattended message.

Impressive evidence of the efficiency of selective auditory attention was reported recently by Mesgarani and Chang (2012). They used multi-electrode arrays implanted within the auditory cortex that allowed them to record activity there in a very direct fashion. Listeners were presented with two messages presented to the same ear but with instructions to attend to only one message. One message was in a male voice and the other in a female voice to facilitate discrimination of the two messages.

What did Mesgarani and Chang find? Responses within the auditory cortex revealed 'the salient spectral [based on sound frequencies] and temporal features of the attended speaker, as if subjects were listening to that speaker alone' (Mesgarani & Chang, 2012, p. 233). Cherry would not have been surprised by these findings.

CRITIQUE OF THE CLASSIC STUDY

As is the case with virtually all research in psychology, Cherry's pioneering study had various limitations, some of which I mentioned previously. For example, researchers nowadays would find it very difficult to publish psychological experiments with remarkably small sample sizes ($N = 1$). In addition, there was an almost complete lack of detail about precisely how the experiments were carried out, and there was no proper presentation of the data or any formal statistical analyses! Nowadays undergraduate students who carried out and reported the findings of their research in such a slipshod fashion would not expect to receive a high mark.

Cherry (1953) assumed that all the deficiencies in selective attention exhibited by listeners in his experiments were due to the complexities and similarities of the auditory inputs. However, by doing so he neglected the demands of the shadowing task that the listeners had to perform. Performing the shadowing task requires much processing capacity, and this may well have impaired performance on the selective attention task.

We can test the above notion by making the assumption that the processing demands of shadowing would be greatly reduced in someone who had prolonged

experience of shadowing. Such a person was Neville Moray, a British psychologist who carried out numerous experiments on the cocktail party problem. He was given the task of detecting digits on the unattended message while he shadowed the attended message. He detected 67% of these digits, which was substantially better than the 8% of digits detected by naïve participants (Underwood, 1974).

Cherry (1953) was specifically interested in listeners' ability to attend to one auditory message while ignoring a second message. As a consequence, he did not consider what would happen if participants shadowed an auditory message while pictures were presented at the same time. Allport, Antonis, and Reynolds (1972) did precisely this and discovered that participants remembered 90% of pictures presented concurrently with a shadowed auditory message. In contrast, recall of auditorily presented words concurrently with a shadowed auditory message was very poor. Thus, the apparently minimal processing of and memory for the unattended message reported by Cherry (1953) is not found when the unattended message is in a different modality to the attended message.

One of the most important limitations of Cherry's research concerned the way in which he assessed the listener's processing of the unattended message. In essence, what Cherry did consisted simply of retrospective questioning: participants were asked at the end of the experiment what they had noticed about the unattended message. This approach may cause an *under-reporting* of what had been processed on the unattended message for two reasons. First, processing of the ignored message of which listeners were consciously aware at the time might have been forgotten by the time that they were questioned retrospectively. Second, as became increasingly recognised in the decades after Cherry's classic study, considerable amounts of processing can occur in the absence of conscious awareness of such processing.

What is really needed is to assess processing of the unattended message online (i.e., while it is occurring). For example, consider the research of Von Wright, Anderson, and Stenman (1975). They instructed their participants to shadow one list of words and to ignore a second list. When a word previously associated with electric shock was presented on the unattended list, there was sometimes a physiological reaction in the form of a galvanic skin response. They observed the same effect when a word similar in sound or meaning to the previously shocked word was presented on the unattended list. Various other techniques have been used (see Driver, 2001). The evidence generally supports the notion that there is partial processing of unattended words and that such processing can extend to the semantic level.

It is important to note that there remains some controversy as to the most appropriate interpretation of the above findings. One possibility is that genuinely unattended stimuli can receive semantic processing. Another possibility was put forward by Lachter, Forster, and Ruthruff (2004). They pointed out that semantic processing of allegedly 'unattended' stimuli may occur because of what they called 'slippage'. By slippage, they meant that attention may occasionally shift from attended to unattended stimuli. The existence of slippage would be consistent with Cherry's (1953) claim that there is minimal processing of unattended stimuli.

There is some support for Lachter et al.'s theoretical position. For example, Dawson and Schell (1982) carried out a study resembling that of Von Wright et al.

(1975) and managed to replicate their findings. However, they also found that most of the increased physiological responses to previously shocked words occurred on trials on which it was likely that the listeners had shifted attention to those words.

Lien, Ruthruff, Kouchi, and Lachter (2010) presented a prime word briefly followed by a target word and instructed participants to decide whether the target word belonged to a specified category (e.g., *sports*). They were especially interested in whether there was a priming effect when the prime word belonged to the same category as the target. There was no priming effect at all when the prime words were not attended, even though these words were each repeated 160 times during the course of the experiment and were highly expected. This finding suggests that (at least in the visual modality) semantic processing requires attention.

Cherry's research suggested that the mechanisms involved in selective auditory attention are relatively simple and straightforward (as can be seen in Broadbent's filter theory). Unsurprisingly, subsequent research has revealed that the actual mechanisms are dramatically more complex. For example, it is correct (but insufficient) to argue that listeners attend to one auditory input and ignore another by focusing on a single difference in their physical properties (e.g., spatial location). In real life, of course, there are often more than two auditory inputs, and these inputs typically differ from each other in several properties.

Shamma, Elhilali, and Micheyl (2011) argued that the physical properties (e.g., timbre, pitch, frequency, spatial location) of any given auditory input tend to display temporal coherence. What that means is that neural responses associated with each of these properties tend to correlate highly with each other. These correlated neural responses provide the basis for grouping together any given auditory input's properties. The process of grouping or binding together an input's properties is facilitated by selective attention. In sum, effective selective auditory attention involves combining information across many stimulus properties in ways that are considerably more complicated than those envisaged by Cherry.

As we indicated earlier, Cherry (1953) obtained evidence indicating that auditory attention depended in part on top-down processes based on using context to predict what words were about to be presented. What Cherry did not do was to distinguish between two contrasting ways in which context might influence auditory attention and perception (Harley, 2013). First, there is the interactionist position, according to which contextual information influences the processing of auditory language at an early stage *prior* to word recognition. Second, there is the autonomous position, according to which context exerts its influence late in processing *after* word recognition.

Research in this area has been somewhat inconsistent (Harley, 2013). In general, however, the interactionist position is more applicable to situations in which degraded speech is presented whereas the autonomous position is more applicable when the speech signal is clear.

In sum, Cherry's (1953) classic study is limited in several ways. First, he adopted a crude methodological approach. Second, he did not appreciate the importance of the demands imposed by the shadowing task. Third, Cherry probably underestimated the extent to which the unattended message was processed because of his reliance on retrospective self-report. Fourth, while he realised that

top-down processes triggered by expectations were of importance to selective attention, he did not distinguish between early and late effects of such processes. Fifth, Cherry underestimated the complexities involved in focusing attention on one auditory input to the exclusion of all other auditory inputs.

CONCLUSIONS

Cherry's (1953) research on the cocktail party problem played a major role in stimulating research into selective attention. Ever since his classic study was published, selective attention has been one of the most active areas within cognitive psychology. In addition, one reason why his research has proved so influential is because he devised a very simple task that nevertheless had direct applicability to the real world. Sad to say, most laboratory research at the time involved the use of very artificial tasks which have no obvious relevance to everyday life.

Lack of ecological validity has plagued cognitive psychology throughout its entire history. A notorious example can be found in research on visual search. Until fairly recently, nearly all research on visual search involved tasks in which the target stimulus was presented at a *random* location within a visual display. This differs radically from everyday life. For example, if you are looking for a friend at a railway station, you do not search the sky or the ceiling of the station but rather focus on the floor and the nearby street. Research (e.g., Ehinger, Hidalgo-Sotelo, Torraiba, & Oliva, 2009) indicates that the single most important factor in real-life visual search (but one totally ignored for many years by researchers!) is the potential relevance or irrelevance of any region in visual space as the location of the target.

In my opinion, the main lesson that Cherry's (1953) classic study has for today's researchers is that he showed them how to maximise the chances of carrying out research possessing ecological validity. What Cherry did was to notice an important psychological phenomenon in everyday life, after which he devised a simple and ingenious way of studying this phenomenon under laboratory conditions. This strategy may sound absolutely obvious. However, tens of thousands of researchers in cognitive psychology fail to adopt this strategy.

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