Cognitive spare capacity: what is it and why does it matter?

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Cognition refers to thinking and memory. So why would cognition be a useful concept for ENTs and audiologists? Audition provides our main channel of communication and when we speak to each other, we want to exchange thoughts and remember what people say to us. Even when we are on our own, we cogitate about what people have said to us: "What did he or she really mean when they said...?" Thus, thinking and memory, as well as audition, are part and parcel of speech communication.

It is not surprising that there has been quite a lot of interest recently in studying the specific role of cognition in speech understanding. In particular, there has been considerable focus on working memory. Working memory refers to the ability to keep information in mind while at the same time thinking about it or processing it. In the context of speech understanding, working memory allows us to keep words and phrases in mind until we have understood the meaning of what the talker has said. In general, working memory capacity is lower in children than in adults and lower in older than younger adults. However, even within a specific age range, there is variation in cognitive capacity. Experimental research has shown that when listening conditions are adverse, individual differences in working memory capacity contribute to successful speech understanding. Working memory capacity is limited. When we listen to speech in adverse listening conditions, information entering working memory may be degraded. If we do not hear a particular utterance, there can be a break-down in speech understanding. In such situations, the listener may keep on processing the degraded speech in working memory in an attempt to resolve its meaning. Subsequent phrases may help disambiguate words that were confused, but working memory capacity can become overloaded. In challenging listening conditions, such as when there is background noise, it is necessary for information held in working memory to be updated and for irrelevant or distracting information to be inhibited on an ongoing basis. Thus, it is not hard to understand why listening under adverse conditions could impose cognitive demands that exceed an individual's working memory capacity.

Adverse listening conditions may arise for a number of reasons. Obvious causes are background noise and hearing impairment. Other causes are fatigue and cognitive load associated with the amount of information the person must process while doing one or more tasks. It is well known that listening in noise can be tiring, especially for people with hearing impairment. When people are tired, they perform less well on working memory tasks; in other words, their working memory capacity is reduced by fatigue. As we have seen, challenging listening conditions often increase cognitive load because more information has to be kept in mind. Thus, there is the risk of a vicious circle in which the adverse listening conditions due to noise and hearing impairment increase fatigue and cognitive load, which can in turn make listening even more challenging. If we add to this that children and older adults may have less working memory capacity to start with, the processing bottleneck in an individual's working memory capacity that may undermine speech understanding in everyday listening situations becomes very obvious.

In our research, we have tried to dig deeper into the role of cognition in listening. We have asked the following question: if working memory capacity is tied up in simply trying to get the drift of the conversation, what cognitive resources are available for processing speech at a higher level, e.g. preparing an appropriate response in

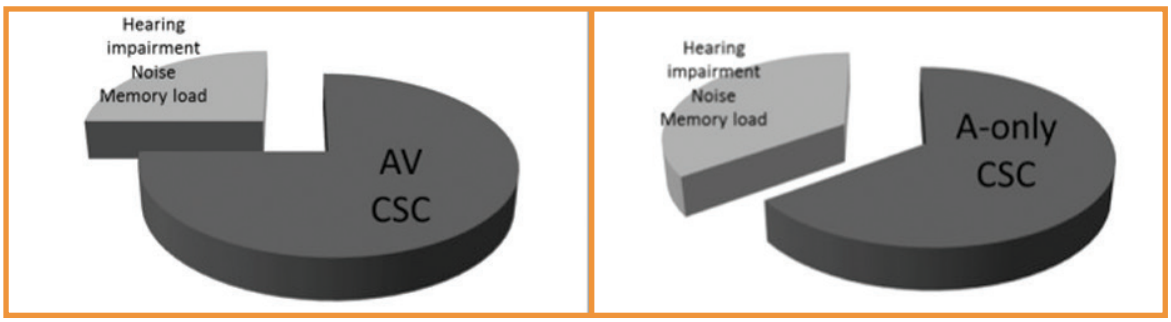

Figure 1. Seeing the talker's face (AV CSC) enhances performance when speech is heard in noise, under cognitive load and with hearing impairment, compared to simply listening to the auditory signal (A-only CSC).

a conversation? In other words, what is the nature of Cognitive Spare Capacity (CSC)?

To find an answer to our question, we developed the Cognitive Spare Capacity Test (CSCT; for details see section below on further reading). The CSCT was developed for research purposes. However, we believe that with some simple modifications this test could be used in the clinic for assessing how different kinds of hearing aid signal processing influence CSC under different kinds of listening conditions. This could provide a tool for optimising everyday listening and social participation for individuals with hearing impairment. The CSCT assesses the individual's ability to manipulate heard information under a range of different listening conditions. In the research version of the task, we manipulated background noise, memory load, availability of dynamic visual speech cues and the specific kind of task to be achieved. During the CSCT, the participant listens to lists of two-digit numbers and is asked to perform tasks such as recalling the two highest numbers in the series. Because the numbers are not arranged in order of magnitude, the contents of working memory have to be continually updated as each new number is presented. Two numbers always have to be kept in mind and each time a new number is heard the participant has to decide whether it is greater in magnitude than either of the two numbers currently being held in mind. If it is, then one of the two numbers being held has to be discarded and replaced with the new number. This may sound simple, but actually it demands a lot of thinking. If working memory capacity is consumed by disambiguating numbers that are, for example, degraded by background noise, performance on the CSCT should be lowered, but if listening is facilitated by some kind of signal enhancement, such as seeing the talker's face or advanced signal processing in a hearing aid, performance on the CSCT should improve.

Our results show that introducing speech-like noise, increasing the number of items to be remembered and removing visual cues reduce performance on the CSCT more for older individuals with hearing impairment than for younger adults with normal hearing thresholds. However, as shown in Figure 1, when listening conditions are optimised by making the talker's face available (AV), or presenting speech in quiet, individualising amplification or signal-to-noise conditions, there are no differences in CSCT scores between the groups we have studied. This pattern of results suggests that an adapted version of the CSCT could become a useful tool in the quest for assessing if a hearing aid fitting has optimised ease of listening and minimised the demands that everyday listening places on cognitive capacity.

Further reading

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Declaration of Competing Interests
None declared

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