102| Working Memory – With Dr. Alan Baddeley

September 1, 2022

NAVIGATING NEUROPSYCHOLOGY

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Speakers: Alan Baddeley, Ryan Van Patten, John Bellone

Intro Music 00:00

Ryan Van Patten 00:17
Welcome, everyone, to Navigating Neuropsychology: A voyage into the depths of the brain and behavior, brought to you by INS. I'm Ryan Van Patten…

John Bellone 00:26
…and I'm John Bellone. Today we speak with Dr. Alan Baddeley about working memory. Dr. Baddeley is a British psychologist and researcher who has had a huge impact on the field of neuropsychology through his work on memory and working memory. Much of what we know and many of our tests of working memory have

been influenced by his work over the years, so we are very grateful to have him on the podcast. Just one caveat: Toward the end of the conversation, he talks to us about his book "Working Memories". Although this product is discussed in the episode, the INS is neither promoting nor recommending any commercially available products that may be mentioned. And, with that, we give you our conversation with Dr. Alan Baddeley.

Transition Music 01:08

John Bellone 01:17
Alan Baddeley, thanks for joining us at NavNeuro here.

Alan Baddeley 01:21
Well, thanks for inviting me.

John Bellone 01:23
Let's start with the concepts of short-term memory and working memory. Could you define and differentiate these terms for us?

Alan Baddeley 01:30
Yes. The term “short-term memory” preceded the development of the idea of a working memory and it essentially encapsulates the idea that you need to hold information briefly in order to do other things with it. Working memory resulted from asking the further questions of, "Why is this necessary?" and "What is necessary?", and looking at to what extent if we blocked standard short-term memory tasks, for example by giving somebody a sequence of numbers to remember, it will prevent other cognitive activities. We found that the extent to which it blocked was surprisingly limited and resulted in our coming up with a more complex concept, which we called working memory, because we wanted to emphasize the function that it was doing important work.

John Bellone 02:24
I want to be crystal clear on definitions before we move forward. Could you talk about the “working” part of working memory, including the manipulation of information? What are some examples of working memory in everyday life? What are some examples of short-term memory that don't involve manipulation? Can you talk us through those?

Alan Baddeley 02:43
Okay. The term “short-term memory” is still used for situations where you simply hold and repeat or hold and write down a temporary message as in digit span - remembering a telephone number while you're dialing. Working memory, on the other hand, involves doing something with the material you're holding. So if I asked you to multiply 27 by 3, you'd need to use working memory because you'd probably multiply 3 by 7 is 21, meanwhile holding the 2 and so forth and so on. Or, in a visual sense, if I asked you to perform a Corsi block tapping test, where you simply repeat a series of spatial taps, that would be short-term memory. Working memory would be if you need to do something with it. So the simplest difference is probably backwards span. With verbal material, you need to find some way of changing the order with which things are presented. People can use different strategies. Some people will use visual coding to help them, some will run through and then pick off the last three. Similarly with visual spatial memory, if you have a task like instructing a friend how to get to the station, you need not only to hold the way to the station in mind, but also pick off information in the appropriate order.

Now, the concept of working memory involves a central attentional system, which we call the “central executive”, together with two temporary systems, one verbal, the phonological loop, that can hold speech-like material and rehearse it and the other, the visual spatial sketchpad, where you hold information in parallel. In both of these, you can rehearse. In the case of the phonological loop, the rehearsal tends to be by saying it yourself. Evidence for this comes from, first of all, suppression. If you stop someone saying the message by having them say "blah, blah, blah", performance drops substantially. Evidence that it's a phonological or sound based system comes from the phonological similarity effect. Many years ago, Conrad demonstrated that if people were trying to remember a sequence of letters, even though they were presented visually, errors would tend to be similar in sound suggesting that people were taking the visual input and turning it into a speech or sound-based code. If you combine articulatory suppression - saying "blah, blah, blah" - with phonological similarity and visual presentation, then you lose the effect. What this suggests is that we have a system that can take visual information, it can use articulation to turn it into a phonological auditory articulatory code, and that if you stop this process it impairs performance because you can't maintain rehearsal in the same way and impairs the transfer of information from a visual representation to a verbal one. Hence, you lose the phonological similarity effect.

In the case of the visual spatial sketchpad, the system doesn't have a direct way of maintaining information. You can impair performance by requiring a visual or spatial concurrent task. So if you have a block tapping task at the same time as a visual imagery task, then the spatial aspect of the block tapping will interfere. Similarly, with a visual aspect, if you present colored shapes, these will interfere with the

holding of the visual representation but the mapping of one to the other is much less straightforward.

Ryan Van Patten 07:01
I've also really liked the idea of working memory as a mental workspace, which I've seen you write about before. I've imagined that this would be useful with some patients. If neuropsychologists are working with patients and they want to know what working memory is, one analogy that makes sense to a lot of people would be, it's your mental workspace. It's almost like a whiteboard in your mind. It's limited in the amount of information that can be held there. You can do manipulations with it - you mentioned multiplication, there are many other manipulations that can be done. But I feel like the mental workspace analogy can do a lot of work for us.

Alan Baddeley 07:39
Okay. I was going to move on to that. I may have produced too much detail too soon.

John Bellone 07:44
[laughs] That's perfect.

Alan Baddeley 07:45
Okay. These two temporary systems feed on to the all important central executive, which is the controller. This is limited in capacity and it performs a whole range of activities forming a mental workspace where you can take information, you can blend it, you could bring it together, you can link it to what's in long-term memory. So when I was using the analogy of explaining how to get to the station for a friend, this involves mental workspace in taking from long-term memory information about the layout of your town and thinking about what your friend already knows, in taking the temporary storage and turning it into visual activity of a sort of visual spatial representation and representing that verbally. So lots of different activities all going on at the same time. Similarly, in multiplying 27 by 3, again, you're performing multiple activities at the same time. You're holding and you're also trying to take information and reorganize it.

One task that reflects this is the so-called “working memory span”. This is based on the assumption that working memory, rather than short-term memory, involves combining short-term storage with manipulation. Daneman and Carpenter, in search of a way of measuring the role of working memory in comprehension, came up with an apparently very simple but very powerful task. This involves presenting, or having a subject read a sequence of sentences, and then afterwards, recall the

last word in each. Surprisingly, this is really rather difficult and the typical span is between three and four sentences. So, it might be - I don't think I can do this myself [laughs]. “The sailor came home from a long voyage. It was a dark and stormy night. His wife was awaiting him at home.” I'm making it easy so that I can remember it. [laughs]

John Bellone 10:10
So, it would be: voyage, night, and home. [laughs]

Alan Baddeley 10:14
You get the message.

John Bellone 10:15
Right.

Alan Baddeley 10:16
I usually have this written down. [laughs]

Ryan Van Patten 10:17
[laughs]

John Bellone 10:17
[laughs]

Alan Baddeley 10:17
It turns out that this task correlates not only with what they were interested in measuring, which was comprehension - as in the Graduate Record Examination, where people who do well on this task also do well on complex prose comprehension - but it also correlated with a whole range of other things ranging from performance on attention/focusing tasks and withstanding distraction through to reasoning tasks that form a basis for intelligence, to skill in acquiring a new programming language. There have now been huge numbers of studies demonstrating this. And that, of course, in turn, raises the question of, "Should this be a source of understanding what's involved in intelligence?" In one sense, it clearly is. It correlates highly with intelligence. There have been quite a number of studies that have tried to tease apart the components and, in general, there's acceptance that the capacity to control the tension, to inhibit irrelevant information is important. But it seems likely that other components are important, too. Attempts to agree these have not been all that successful. In some ways, it's rather like the

old psychometric question of whether general intelligence, *g*, has multiple components or a single component. It turns out that there is a single component that has contributors from the others. But, effectively, it's probably best regarded as an alliance of systems that work together, which for practical purposes one could identify particular tasks that seem to work in a particular context. There are a number of ways of doing this. One is to have lots of multiple tasks, which have been originated by Weschler, and other is to try and focus on one like the Raven's matrices. They both have strengths and weaknesses and they're linked to, I think, the concept of working memory as a system for manipulating information.

Ryan Van Patten 12:45
Great.

Alan Baddeley 12:46
[cross talk]

Ryan Van Patten 12:47
Sure. If it's okay, I'll ask a little bit about the multicomponent model, broadly, which you had introduced and started to describe. I wanted to anchor our listeners to say that you proposed a multicomponent model of working memory with Graham Hitch in 1974...

Alan Baddeley 13:05
Yeah.

Ryan Van Patten 13:05
...and there's a rich history to the model, which you discuss in many different outlets. I wanted to plug your 2019 book, "Working Memories" right now, which we can talk about more.

Alan Baddeley 13:16
Good.

Ryan Van Patten 13:16
But, for now, let's just talk about the current state of the science with respect to the multicomponent model. You have mentioned a few of the four parts - there's the phonological loop, the visuospatial sketchpad, essential executive, and episodic buffer. So maybe we can linger on the phonological loop for just a few minutes. Tell

us what it is, why we think it may have evolved in humans, and how we use it in our daily lives?

Alan Baddeley 13:43

Okay. We started then with a three component model, which had an attentional controller and two supportive systems - one visual spatial and one verbal. We decided that we would try to unpack this three components system and to start with the phonological loop the verbal part. We did this because we thought this would be the simplest and the one that we knew most about. We came up with a very simple concept of a phonological storage system and an articulatory rehearsal system. Evidence for the phonological aspect of the system came initially from Conrad's demonstration that remembering sequences of verbal material, like letters, appear to operate acoustically or verbally. He showed that if you present a sequence of unrelated letters, even though they're presented visually, errors would be acoustic in nature. So B might be represented as V rather than R which would be more visually similar. He argued that this therefore suggested an acoustic system.

John Bellone 15:04

I was wondering - you know, reading obviously relies to a great extent on phonological skills. I'm wondering how the phonological loop might relate to learning to read as well as learning disorders in reading.

Alan Baddeley 15:21

The phonological loop is a system for holding sequences of sounds and particularly spoken sounds. Having demonstrated, using the short-term memory patient PV that she had difficulty in holding sequences of sounds, we began to explore the question of whether this would also occur in normal children and in children with specific learning impairment. We found that children with specific learning impairment did have impaired phonological loop and also that they had trouble in hearing and repeating back novel pseudowords, and they had trouble in learning to read. So we went on to look at the relationship between the capacity to hear and repeat back words and the acquisition of vocabulary in the first place. Here, we found that 4-year-old children, their capacity to hear and repeat back a nonword, multisyllabic nonword like *sarindeep* or amulab is quite closely correlated with their acquired vocabulary. As children get older, the link remains but becomes weaker because vocabulary depends more on richness of auditory and visual input. But we also found that children who were classified as dyslexic also had a problem in nonword repetition, and that their performance was rather like that of younger-aged children. We didn't find that their errors look like acquired dyslexia but it was as if it was just less well-developed. Non-word repetition is now, I think, quite widely used as a measure associated with looking at reading difficulties. We assume that the

operation is that as you read off visual sounds, you need to hold them in mind and put them together. It's the capacity to hold and put together that depends on the phonological loop. So it's not that phonological awareness is not also important, but phonological storage is a component that's probably necessary for many tasks of phonological awareness. They work together.

John Bellone 18:10
Yeah. Right. It's necessary but not sufficient. I know you introduced the visuospatial sketchpad already, but can you give us a broad overview of what the visual spatial sketchpad is?

Alan Baddeley 18:25
Yeah. The sketchpad is a system for holding visual and spatial information and binding them together into visual-spatial representations. It's fed from a number of different streams. For example, shape and color come together and are bound together with other representations [like] the spatial location. Similarly, tactile information also flows together into the system, bound into representative objects that are then accessible to conscious awareness via the system called the episodic buffer.

Ryan Van Patten 19:11
I'd like to talk for a few minutes about this well-known dichotomy in the neural processing of visual information. It was developed primarily in primates, [and] it's known as the "what," or ventral, pathway versus the "where/how," dorsal, pathway. Just for our listeners, in a very simplistic sense, information about object form and shape tends to move along a network from occipital to inferior temporal areas, that's the ventral pathway, while information about spatial location and motion goes from occipital to parietal regions, the dorsal pathway. We think about this when talking about pure visual cognitive processing, but it's not always applied when considering working memory. So how does the “what” versus “where/how” distinction map onto the visual spatial sketchpad?

Alan Baddeley 20:06
Well, I think the “what” and the “where” come in as separate spatial and object properties, so it fits perfectly well with separate streams that have to come together. The sketchpad occurs beyond this point and is fed by these separate streams. In fact, in general, the conscious awareness of information comes through the episodic buffer, which has streams from a number of different areas of the brain - verbal, visual, long-term memory, and instructions for action. So in terms of the neural underpinning, I think this is highly complex and I think, at the moment, we're

only starting to understand this. We're coming at a much later stage when things are coming together but there is good evidence, for example, that shape and location are encoded separately and brought together. And obviously verbal and other information again, separately, and brought together and then combined in the episodic buffer.

John Bellone 21:25
I'm curious how we can use both visual and verbal information to help one another out. How can we use verbal strategies to help us remember visual information, which I believe is sometimes called verbal mediation? You had alluded to it before. Also, is it possible to use visual strategies to help us remember verbal information, using visual imagery for example? Do you have any tips about that?

Alan Baddeley 21:50
I'm not sure about tips.

John Bellone 21:53
[laughs]

Alan Baddeley 21:53
Basically, there's lots of evidence that the two can work together. The classic visual spatial imagery tasks where you have a framework - in medieval times it would be a cathedral with certain locations you're trying to remember. In those days [it was] probably Acts of the Apostles or something, and each one would be attached to a location and the locations would have this sequence. A much more banal example is remembering a shopping list by remembering parts of your house. So the bananas are on the front door, the tomatoes are on the front doorstep, and so forth. But there are lots of ways in which this can happen spontaneously. I'm trying to think of some, I'm not very spontaneous at the moment.

John Bellone 22:50
[laughs]

Ryan Van Patten 23:00
Let's move on to the central executive which you've mentioned - the controller of attention. The central executive is closely linked to the Norman and Shallice supervisory attentional system. In their model, they differentiated automatic habitual behavior from a top-down controller, the supervisory attentional system. These concepts may sound familiar to some listeners because they resemble the system

1 and system 2 distinction, which was popularized by Daniel Kahneman. But sticking to the central executive, what is it? Why is the Norman and Shallice model so important to it?

Alan Baddeley 23:41

Okay. After we'd been working on working memory for about ten years, I was invited to write a book on it. Everything went smoothly until I realized that I got to the end and hadn't said anything about the central executive. Other than that it was an attentional system that could do lots of clever things. Now one of the problems was that there seemed to be no models or potential systems that were concerned with control of action, rather than control of perception. There was, however, just one exception that of Norman and Shallice, and this aimed to solve two types of problems. One was Don Norman's interest in slips of action - things like making a mistake when you're driving to work. Say [you're] driving to the supermarket on a Saturday and you unintentionally end up at work. Or much more problematic where you make a mistake in running a nuclear power station and end up in meltdown. Shallice was much more interested in the frontal lobes and explaining the way in which they worked. They came together in this two component system which assumed control of behavior by a whole series of systems that were based on habit and control of habit, relatively automatic systems, together with the supervisory attentional system, which depended on the frontal lobes. We adopted this as the basis for the central executive, and have focused principally on trying to further develop the concept of a supervisory system. Our development was rather different from Tim Shallice, who has relied principally on neuropsychological evidence and on computational modeling. We depended mainly on behavioral methods and moved forward much more tentatively and much more gradually.

It seemed to be working reasonably well until we encountered a series of problems. We had assumed for the case of simplicity that the central executive was a purely attentional system and that all the storage operated either long-term memory or in the two subsidiary systems, sketchpad or the loop. If so, how could this operate? And, in general, in understanding prose, for example, it was clear that people were able to bring together verbal and visual information to set up and imagine a scene and then answer verbal questions about it. How could this happen without storage? So we came up with the idea of a fourth component, the episodic buffer. This is a system that acts as a sort of blackboard but a very three dimensional, multidimensional blackboard where information comes together as integrated episodes that can be manipulated by the executive. I proposed this rather tentatively since it was very speculative. And somewhat to my surprise, it met with considerable interest and has now survived for 20 years.

We were, however, rather concerned that it could just be a way of explaining away anything. "Oh, it just happens in the episodic buffer." So we decided we need to put constraints on it and use it in order to ask and answer questions. We started with the suggestion that it was dependent on the central executive to bind together information from these sources, so the executive as a crucial binding mechanism. We went through using our various ways of manipulating the different components through concurrent tasks to ask, "Could we prevent binding by blocking any of these?" And the answer seemed to be, “No we couldn't.” So we looked, for example, of binding color and shape into memory for an array of colored shapes and we loaded the central executive, or the sketchpad, or the phonological loop and looked at performance on this. We found that overall performance dropped but not binding, suggesting the binding was happening at an earlier stage. In the case of verbal information, we looked at the binding of information into sentences and clauses. Again, we found that if we blocked any of the systems, they would slow down and impair performance, particularly the phonological loop and the central executive, but it didn't interfere with binding per se, suggesting that the binding was happening off stage and was being brought together and then manipulated. So, in some ways, this left us with a model that had some similarities to Nelson Collins.

John Bellone 29:23
So, in your original model, the 1974 model, it was just like we had mentioned before - the central executive and then the loop of the sketchpad. Then in 2000, I believe, it was where you then added the episodic buffer to the model, and that's how it survives today as these four main components. My understanding is that the episodic buffer also ties in long-term memory stores as well here.

Alan Baddeley 29:52
And conscious awareness.

John Bellone 29:53
Conscious awareness. Right.

Alan Baddeley 29:55
[unintelligible]

John Bellone 29:57
Right, right. True. In terms of the central executive, I was thinking of giving our listeners an example of how that might work. So in driving, let's say, if someone is talking on the phone and they're driving, which, you know, maybe they shouldn't be

doing, the central executive is constantly switching between the two tasks. Do you want to say anything about a real world example of this process?

Alan Baddeley 30:23

Yes, a good example of the role of the central executive is in driving. In fact, a study carried out many years ago, my old unit involved people driving around the circuit and choosing to go through polystyrene posts and they had to decide, was it wide enough for the car or not? And they were monitored while doing this. At the same time, they had to solve simple reasoning questions like the ones: "A is followed by B. B-A. Correct or not?" This impaired performance, however, it didn't impair the capacity to steer but it did impair the capacity to make a judgment of how wide the gap was. Many years later, this has been followed up by abundant evidence indicating that the problem is typically not what's happening with your hands but what your mind is doing. Listening to music or something is probably fine. But if you're trying to negotiate a deal, forget it. I remember a horrifying situation coming from San Francisco with a taxi driver who had his own small company. He had a customer, an irate customer at the airport, and the last driver at the other end - two mobile phones. And we were just praying.

Ryan Van Patten 31:55

[laughs]

John Bellone 31:55

[laughs] Yeah.

Alan Baddeley 31:59

That's an extreme example, but it's what the executive is doing. That's very important.

Ryan Van Patten 32:07

Right. That real world example can be helpful for people in terms of what they're doing while they're driving. I think it's pretty well accepted that it's dangerous to be sending and receiving text messages while driving because you are not looking at the road. But it may not be as well appreciated that it's not just where your eyes are. Like, eyes on the road is helpful, but if you are mentally distracted by something complex, like you described, then that reduces your ability to solve problems and to make judgments. So, if there's roadwork and the road becomes more narrow, for example, you may be at risk for an accident.

Alan Baddeley 32:49
Sure.

Ryan Van Patten 32:50
I wanted to move into neuroanatomy and ask you one question about this. When people think about working memory and what parts of the brain are important for it, I think the dorsolateral prefrontal cortex, the DLPFC, and the anterior cingulate often come up for people. But, of course, the reality is more complicated than just two discrete brain areas. So, what neural networks are responsible for working memory?

Alan Baddeley 33:19
A great many. [laughs] I've intentionally avoided this because I really don't know too much about the neuroanatomy. I've never really had the facility to work at that level. I've basically worked in neuropsychology when I have a neuropsychologist to work with. Nearly all the early work was done when we didn't even have access to CT scans. While I got enthusiastic about neuroimaging in the early stages, my feeling is that the working memory system is sufficiently complex that, up to now, the neuroimaging work has not proved enormously fruitful. I think, at a broad system level, it's useful. I think it's now beginning to be more fruitful and more useful. But I'm not a great enthusiast for a lot of the work that's been done on using neuroimaging. I think, in particular, a lot of it is correlational. This area is activated when this task is performed. The task itself is often complex, the area itself may or may not be crucially involved, the conclusions that can be drawn are limited, and often the reliability is not great. So, I'm not the right person to ask about the underlying neuroanatomy.

Ryan Van Patten 34:52
Fair enough.

John Bellone 34:53

I'm curious what your view is on the state of the literature on training working memory? In particular, we can directly train working memory in a lab environment, but can we then experience far transfer to other real world tasks in our daily lives? What's your take on this literature?

Alan Baddeley 35:15

I think the evidence now from a substantial number of studies is that it is possible, given appropriate training, to transfer to broadly similar tasks. Typically, the [unintelligible] tasks, but that transfer more generally tends to be absent or weak. I

think it's possible that one can train attention - train, for example, to shut out irrelevant stimuli - and that one can train components of a task. But I think the idea of broad training of working memory doesn't seem to be very promising. I think, at the moment, most people who are in the area are looking at trying to find specific tasks that can be trained. I think the next stage is probably to select real world tasks that are important, to analyze what aspects of working memory are necessary to train for that, and then training them rather than broad spectrum training. Whether that will be successful, I don't know. I think it's going to take some time to find out.

John Bellone 36:36

I like that approach. I wanted to move into a couple of clinical questions. I know you said you're not a clinician, but I'm curious if you have any thoughts. If you prefer to skip this one, that's fine, but there are many tests that are designed to measure working memory that are available to us as neuropsychologists. We've mentioned the Digit Span and you mentioned the Corsi block tapping tests, but there's Symbol Span, Spatial Addition, the PASAT, and Auditory Consonant Trigram - there's so many. I want to hear you talk about potential clinical applications to some of these tests. Maybe it'll help to frame it in a hypothetical situation. So if a clinical neuropsychologist came to you looking for advice on choosing tests for the working memory aspect of their cognitive battery, for maybe a typical older adult who has some complaints of memory loss, I'm curious what your response to them would be.

Alan Baddeley 37:35

I would be inclined to keep it simple. To use Digit Span And Corsi. There are more complex tasks that you can use. I think in the case of central executive, I did - in fact I was the Wechsler professor at the University of Texas for a semester and was asked by the then-test publishers would I be interested in contributing to the Wechsler memory test, which I declined because I didn't think it was a very good test. But I said I'd be happy to advise them on working memory, which they declined. Then, some 18 years later [laughs], I was asked again, together with Randy Engle and Nelson Cowan, if I could advise them. I noted that over the years what had happened was that they had taken tasks that were already there and manipulated them slightly to some extent, [and] relabeled them as working memory. They certainly involved working memory, nearly all the tests involve working memory. I ended up actually suggesting they go along with Nelson and Randy, who've done a lot of individual difference work. Central executive tasks tend to be complex and messy. So, in a sense, you want something that's complex and messy that picks up executive processing. It's not a scalpel. You need to have something that can be done by a wide range of people, including patients. That's essentially the question of refining existing measures. I think they've probably by now gone

ahead with that. So I don't have specific recommendations for working memory. In fact, nearly all the practical work I've done in neuropsychology has been in long-term memory. I'd be much more useful in applying my skills to long-term memory, whereas actually neuropsychology has been much more helpful to me in providing ways of investigating working memory. It would be nice to be able to feed something back, but given that we can't train working memory and given that, on the whole, the cases of very precise specific working memory deficits are hugely helpful, but very rare, the theory and the practice haven't gone together as well as one might have hoped. I've gained hugely from neuropsychology, and I've tried to give something back through long-term memory.

John Bellone 40:36

Can you talk about the importance of - Well, while we're talking about this neuropsychology clinical versus research, talking about this dichotomy a little bit, can you talk about the importance of lesion-based case study research on the development of your multicomponent model?

Alan Baddeley 40:54

Yes. Single case studies of patients with very specific cognitive deficits have been hugely informative. It's not correct to define these in terms of lesions because very often the lesions are not necessarily very specific. In the patient that I studied with FLR, who has a very, very precise and specific phonological loop deficit, she has a rather broad lesion but the underlying cognitive functions are well preserved apart from this. Similarly, the work I've done with Elizabeth Warrington on amnesic patients have been on carefully selected patients who have very specific episodic long-term memory deficits. Their lesions were not necessarily very specific and, indeed, in the early stages, it was difficult for us to obtain information on precise lesions so they were defined in terms of their functional deficit. It was their functional deficit that was informative.

John Bellone 42:14

Right. This was before neuroimaging techniques. Nowadays...

Alan Baddeley 42:18

Yes. I think it's still true that the mapping of lesions onto certainly very specific deficits is a long shot. You occasionally get a very informative patient who has a very specific deficit and then you learn from this and then you extend it to a wider range of patients whose characteristics are broader and may well be lesion-based. But, usually, their lesions are not precise. There are several, and you probably have

several deficits and so it becomes more practical to use it, but less theoretically informative.

John Bellone 43:02

I agree completely. I can speak to that [in] working in a rehab hospital and seeing patients with stroke, traumatic brain injury, and it's not a clean [laughs]. It's not a clean picture like our textbooks tend to portray it to be with the specific lesions and dissociations. It's a lot of the time much more messy than that.

Alan Baddeley 43:23

I think the same also applies to etiology. A lot of the early work on amnesia was done on Korsakoff patients who were originally described as having pure deficits but they didn't behave like Elizabeth Warrington patients, they were much messier. Eventually, it turned out that they didn't have pure deficits. They had frontal lobe damage as well. So it's important to map what one sees onto etiology and so forth, but to extrapolate in the other direction with caution.

John Bellone 44:02

Yeah, that flexibility is pretty key for us as clinicians. To very quickly talk about the importance of studying memory and working memory from the higher order perspective of psychology, which is, like you mentioned, where you've lived for the bulk of your career, if I'm not mistaken, rather than the so-called reductionist approach of looking at neural systems or even single cell recordings, I wonder if you have anything to say about this difference in levels of investigation?

Alan Baddeley 44:34

Okay. I think it's important to have theories at a number of different levels. My concept of theories is that they're rather like maps. They're useful artifices systems that help you to understand what you know, and to ask questions about what you don't know. What you do is to try and encapsulate as much as possible, and then extend it in different directions. The map analogy - I sometimes use the London Underground where an underground map is very useful if you're studying how to get from A to B by the underground, not if you're walking, and certainly not if you're driving. So I think, as a cognitive psychologist, I operate at the level that is between the social on the one hand and the neurobiological on the other. More specifically as a neuropsychologist, and more psychologist than neuro, I work with neuropsychologists who look after the other side. I think if you're extrapolating from one to the other, it's usually much more fruitful if the two are close together and that if there aren't too many steps. Colleagues who worked on basically consolidation of the memory trace and the neural basis of that, we'd be interested in the same thing,

but couldn't really talk to each other fruitfully. Now, neuropsychologists who look at behavior and map it onto the brain aren't much closer. I've been fortunate enough to work with people who both see patients and understand the cognitive psychology enough to know when an interesting patient crops up, and that I can then work with to ask further questions and bring to bear what I know from the laboratory to the clinic. So I think it's important, but it's dangerous if you've tried to extrapolate too much for too far. So I think, fine, we need to work together, but perhaps not be too ambitious at switching from one to the other.

Ryan Van Patten 47:22

The multicomponent model, or the MAP, as you mentioned, I like that analogy a lot, but your model has been remarkably robust and flexible over the years. We mentioned that you originally proposed it in 1974 with Graham Hitch and it's still highly influential today. It's been nearly 50 years since its inception. I'd like to hear you talk for a few minutes about developing and refining scientific theories in cognitive psychology and neuropsychology.

Alan Baddeley 47:51

When I first graduated, back in the 1950s, there was a lot of interest in scientific theory and what a theory should look like and, indeed, in psychology - “What's psychology of science? What should it look like?” In general, the philosophers tended to think that it should look like Newtonian physics and it should have equations and laws and things. Influence from the Vienna circle suggested that if a theory could not make testable predictions, it was not a valid theory and, in fact, they declared it meaningless. This is a guy called Karl Popper and I believed this for a while till I realized that the things that I was working on no way could I - well, I could easily come up with concrete predictions by making lots of assumptions, which were almost certainly all wrong.

Fortunately, there was another philosopher at the time called Stephen Toulmin, who said that theories are like maps. They're useful ways of organizing what we know, asking questions about the future. If the questions come up with a negative answer, that's useful information. You don't have to throw the whole theory away. My first paper was actually testing a theory of animal learning, based on the model of Clark L. Hull, a guy in the ‘40s and ‘50s who came up with a model of associative learning based on maze running in white rats that was explicitly couched in Newtonian terms. He was very influential for a while and I liked him as an undergraduate because you could see what his simple model said. I could think, “What would be a task that would stress this? What would I do? Would the rat do the same?” I came up with my masters at Princeton and ran an experiment that showed that rats were

smarter than Hull predicted. By the time it came out, however, the whole edifice had collapsed within two or three years and nobody ever read my paper. [laughs]

I decided when I built the theory, I'll build it close to the data. And so we built intentionally keeping broad areas of framework, rather than specific predictive models. Now, I accept that within this broad framework, it's necessary to fill it in. Some of this will need to be more specific [and] mathematical. So, in the case of the phonological loop, the original model didn't have any explanation of how serial order was maintained. My colleague, Graham Hitch, undertook this and there's now substantial literature on this that has presented a range of apparently different models that are now tending to cohere into a series of much more formal and detailed models. So I see the working memory model as a broad framework. I think, if it's going to be applicable, it has to be relatively simple at one level. And I think the three component model continues to serve that. The episodic buffer is a further layer of complexity, but it's the three component model that can be picked up and used by people in second language learning, for example, or in teaching reading. I think that's why it survives.

So if we take the phonological loop, it needs to be connected to both speech perception and speech production, and almost certainly evolved from these two. We need to have people who understand articulation and speech reduction and link up with that, and we're starting to do this. We've been looking recently at ways of trying to help people learn a foreign accent and asking whether it's the articulatory part or the auditory part that's crucial. We also need people who are interested in hearing and, of course, people who link it up with long term memory and meaning. So all of those are directions in which it can be expanded and elaborated while still keeping a sort of rather general focus where the information flows together.

I think my contribution is to have a nice broad framework that encourages filling in the gaps in between because the gaps are going to be exciting areas that someone else is working in and hopefully can be interested in linking into working memory. It's obviously a long, complicated job, but I'm delighted that it's still hanging in there after 40 years [laughs], and that I'm still enjoying it.

Ryan Van Patten 53:21

It's quite an accomplishment. I have to say, as an academic, you've had a huge impact on neuropsychology to the point where you were awarded the 2020 Distinguished Lifetime Contribution to Neuropsychology award by NAN, among many other awards you've won in your career. So I wanted to say congratulations, and thank you for all of your contributions to our field. I wanted to give you a few

minutes to talk about your recent book. It's called "Working Memories," with a subtitle "Postmen, Divers and the Cognitive Revolution".

John Bellone 53:54
I got to say first that "Working Memories" is the perfect title for a memoir for someone who's devoted their career to working memory and other types of memory.

Alan Baddeley 54:03
Yes, it's something that I've wanted to write for a long time. I've led a very interesting life, where I think I worked in five different labs in the first three years of my life. I graduated in London at a time when things were really exciting. Just postwar, the earlier developments like Gestalt psychology were still there. Behaviorism, ethology, animal behavior, cybernetics, and lots of other things. I had a year as a graduate student at Princeton before coming back and trying to find a way of prolonging my PhD as long as possible because there weren't any jobs. I almost ended up in a Neurological Institute with a guy called Grey Walter, who invented CNB and multiple electrode recording that fell through and I ended up under Donald Broadbent at the Applied Psychology unit the year he brought out his classic text. Since that time, I've been involved in combining basic and applied psychology.

I work on memory because that was the job I was given, but I've always maintained interest in other things. I've always enjoyed the challenge of applying psychology outside. So areas like research on divers, because I was an amateur diver and I could persuade my colleagues to serve as subjects and I could persuade the Medical Research Council to help fund my holidays in the Mediterranean [laughs]. I began research on nitrogen narcosis, which was at that time called the rapture of the deep, then discovered that my effects were largely due to the fact that my divers were terrified of being at 100 feet under the Mediterranean and maybe even more terrified off Scotland. So I moved to parachuting and then moved on from that, because it's rather hard to control those situations, to setting up a group concerned with cognition and emotion that set up the Journal of Cognition and Emotion and have done classic work, for example, on mindfulness. Similarly, I've worked on neuropsychology and a series of collaborations when I happen to have access to a sympathetic and talented clinical neuropsychologist, and I've had lots of those. And there would be gaps when I had no access to patients. My work with patients has involved a range from classic amnesic syndrome, Alzheimer's disease, schizophrenia, and, more recently, I'm working on accelerated long-term forgetting in temporal lobe epilepsy. Then, at a unit I got asked to advise the government on various things, whether the jewelry and fraud trials could understand the judge's

summing up, the answer was no. Did they do anything about it? No. Are requests from Margaret Thatcher, should she introduce lie detectors to government? I've pointed out that we've given advice previously, and it had been cited and was not accurate. We would go to the press if we said we didn't think it was a good idea and she said it was. Anyway, we didn't think it was a good idea and she agreed it wasn't a good idea. [laughs] Lots of areas like that. So I love doing applied work.

I've had lots of chances to travel the world. I've lived in the US on five different occasions. I've had sabbaticals in Australia, New Zealand, and Canada. I'm still working on several different things in working memory and long-term memory and I'm now 87. So I've always wanted to write about this. What I wanted to do was to combine the autobiographical, what it was like - so one chapter on what it was like to arrive as a recent graduate in the US in 1956-1957 and then travel from Princeton by rode over to Los Angeles and then travel back, and then back to England and work as a hospital porter; what it was like to work in neuropsychological clinical situations; what it's like to work with government committees - and just pull that together with the background or the history of how cognitive psychologists developed using, in particular, the development of memory because I've been involved in the work with the US from my graduate student days. I've been part of the long-term memory scene, not a very active part, but always active somewhat my whole life, but my main contribution has been through neuropsychology, through patients with working memory deficits and notably through memory impairment and patients with problems in executive control. So I wanted to write this and I've written it. You've got lots of nice things said about it, but nobody seems to review books these days. It won a prize from the British Psychological Society, but I have trouble finding two reviews to send it. Fortunately, they were very positive. They will do.

Ryan Van Patten 1:00:25

[laughs] Yeah. Well, you've had a really interesting career and we're fortunate to have your time today to chat. So, thank you. Before letting you go, we have two bonus questions and these are about the field of neuropsychology specifically - they may relate to working memory, but they don't have to. If there's one thing you could improve about neuropsychology, what would it be?

Alan Baddeley 1:00:52

I don't know enough about neuropsychology, but in areas that I didn't know something about, one of the things that I've done is to take concepts developing in cognitive psychology and turn them into tests that are reliable and patient-friendly and that target a specific problem. However, getting these out into the field is extremely difficult. It used to be the case that there were a lot of small companies

that would handle this because it's a small market, the neuropsychology market, in terms of the assessment of brain damage, and so forth, compared to the intelligence market. But these companies have gradually been taken over by bigger and bigger companies that are part of much larger organizations. So it's very hard to bridge the gap in terms of taking practical steps because I want not just to know how this is linked, but to hand something over and say, “You can use this. This is a tool. [You] don't have to just think about it, there's a tool that embeds the concept.” That bridge that was there is no longer there, and the promotion is no longer that. So a lot of that promotion was through working with Barbara Wilson, who was very active in the rehabilitation area and talked about studies and about tests, including the Rivermead Behavioral Memory test, which is one that I worked on with her. It was her test but we worked on it together. That has been widely successful and translated into some very large number of languages. But other tests that are rather closer to mainstream neuropsychology, it's not easy to get across. So that's one.

John Bellone 1:02:57
Yeah, clinicians have their go to tests and there's a lot of inertia that's preventing the field from adopting other tests and technologies.

Alan Baddeley 1:03:06
I think I understand this. I'm just currently involved in trying to share a report on memory and the law. It's clear that, if you're going to testify on something in a court, you need to have very large numbers behind you, I suspect, because if not, then the other person is going to say, "Well, when was that updated?"

John Bellone 1:03:34
[laughs]

Alan Baddeley 1:03:34
It may be totally irrelevant, but within a court, I can understand why. But it'd be nice to have a way around this.

John Bellone 1:03:43
Yeah, I agree. All right. Our last question for you: What is one bit of advice that you wish that someone had told you during training, or that someone maybe did tell you, that really made a difference for you? Just an actionable step that trainees can take.

Alan Baddeley 1:04:00
Well, the only thing that springs to mind [laughs]... When I was doing my PhD, I would write up my last experiment with great enthusiasm and take it to Conrad, my boss, and he'd say, “When did you finish writing it?” I'd say, “I've just now.” He said, "Take it back. Leave it for a week. Read it, and then bring it back." [laugh] So I don't think that's going to be very much help with your patients, but I'm really not someone who understands much about dealing with patients. I've just been very lucky in working with people who are very good at that.

John Bellone 1:04:41
Well, it's good advice for trainees who are doing their own research, but also writing clinical reports. I find that that is true for me. If I write up an impression section of a report and then leave it, revisit it the next day, sometimes I make some tweaks [laughs]. I'm glad I waited before sending the report to read it again with fresh eyes.

Alan Baddeley 1:05:06
It also applies to reviewers. I wrote a piece and I got the comments from a colleague on it yesterday. Lots and lots of red ink. I glanced at it and I was furious. "All this? Changing all this?" [laughs] And then when I read it in detail, in fact, that was very reasonable. The same goes with referees' reports. [I] initially bristle a bit, but leave it, go back and read it again, sleep on it, and it turns out usually not to be so bad at all.

Ryan Van Patten 1:05:44
I've had the same experience, the idea of coming at it with fresh eyes, having taken at least a few days, if not a week or two, depending on the document and how long and extensive it is. It helps so much to go away and come back. I see mistakes that I missed. I see new ways of organizing a paper or writing it in a way that sounds better or reads better. So, good advice. That's all for our questions. I think we're questioned out. Thank you so much for your time.

Alan Baddeley 1:06:14
Well, thank you. Hope you can make sense of it all.

John Bellone 1:06:17
[laughs]

Ryan Van Patten 1:06:18
Thanks so much. Take care, Dr. Baddeley.

Alan Baddeley 1:06:21
Bye now.

Transition Music 1:06:21

Ryan Van Patten 1:06:26
Well, that does it for our conversation with Alan. We hope you enjoyed it as much as we did. And, as always, thanks so much for listening, and join us next time as we continue to navigate the brain and behavior.

Exit Music 1:06:38

John Bellone 1:07:02
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Ryan Van Patten 1:07:13
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