The dual process theory as applied to bryological identification

Following Mark Lawley's article on the psychology of discovery in the June 11 issue (vol. 104), **Jonathan Sleath** looks at how a psychological model known as dual process theory, normally applied to medical diagnosis, can be used to describe the cognitive processes behind bryophyte identification.

I have often been struck with the similarity between the processes of bryological identification and medical diagnosis. Both involve observation and the gathering of information, often followed by further investigation and the use of other resources, to fit what is encountered into a specific category. Of course the result is not always the correct one, and the consequence can be serious. An incorrect medical diagnosis can lead to a poor outcome for the patient, and a misidentification can corrupt an entire bryological database.

There have been a number of models proposed over the years to look at the cognitive processes used by doctors to reach a diagnosis. Over the last 10 years, Pat Croskerry, Professor of Emergency Medicine at Dalhousie University, Canada, has had a particular interest in how looking at the mechanisms involved in reasoning can help reduce diagnostic error. He has used the work of cognitive psychologists to raise the awareness of biases in our thinking and has proposed a model of reasoning that uses the dual process theory to bring together many of the approaches of the past into a coherent model. He feels that if we are more aware of how our minds work when we reach a medical diagnosis, we can be more vigilant for error, and end up with greater accuracy. Having made my own share of incorrect diagnoses and bryological misidentifications I feel that the same approach could help bryologists.

The dual process theory builds on the dichotomy between analytical and intuitive thinking that has been recognized since classical times, and recognizes two main systems of decision-making.

The first, or System 1, is the intuitive approach that depends on recognition of overall patterns. The experience of the person determines how accurately the information is interpreted. This is akin to recognizing the plant's overall 'jizz' (a word which has somehow crept into our vocabulary), which allows an identification to be made using mental shortcuts or heuristics. We may not have all the possible information available, for example cell size, but we do the best that we can. This is sometimes called bounded rationality. It often occurs without conscious effort, and the processes appear to be hard-wired into our brains. For example, when we glance

△ *Atrichum undulatum*. I. Atherton

at a particularly distinctive plant, say *Atrichum undulatum*, the name springs into our head instantly.

The second, or System 2 process is an analytical scientific approach, involving critical thinking and logic. More information is collected and is available for the testing of hypotheses and analysis of the data. It requires conscious effort to cope with the detail and is more rigorous scientifically. A number of strategies can be applied during System 2 processing. For example arborization, or multiple branching, is an algorithmic approach that is very familiar to us in the use of identification keys. Much of the decision-making process has been done for us by the maker of the key, although we still have to search out the information required. The exhaustion strategy involves collecting all the information possible and then searching for a diagnosis. Croskerry says that this is a common approach of the novice, as well as under conditions of sleep deprivation and fatigue. I cannot be the only person who has had to resort to flicking through the illustrations in a flora after a long, weary and frustrating evening at the microscope.

System 1 works well for most of the time, and usually we end up with a correct identification. We see it classically in action on a field meeting when a record card is filled in by people calling out the names of species as soon as they see them. It is fast and has a high capacity. It requires relatively low effort and brain power but it is very dependent on the experience of the individual and is relatively prone to error. It can process several channels at once and seems to be a primitive way of thinking, rooted in our evolutionary past. Repeated System 2 processing leads to learning, pattern recognition and a System 1 response as we become more experienced. The wrong identification will be made if the pattern is mistaken for a different species, or if a species is encountered in an atypical form. It is heavily dependent on the environment where the decision is made (for example acid bog versus calcareous grassland), but is also prone to biases that influence us consciously or subconsciously and can make it vulnerable. Below are listed some that can be relevant:

- *Anchoring* – the tendency to become anchored to a specific feature early on in the identification process and to jump to a conclusion too early. Very much a problem with System 1 processing.
- *Ascertainment bias* – when what we hope to find influences our thinking.
- *Bandwagon effect* – the tendency to accept an identification just because many other people have accepted it.
- *Confirmation bias* – the tendency to only look for confirming evidence to support the original identification.
- *Multiple alternatives bias* – a large number of

possible alternatives makes it more difficult to decide on an identification, so we tend to fall back on the safest choice.

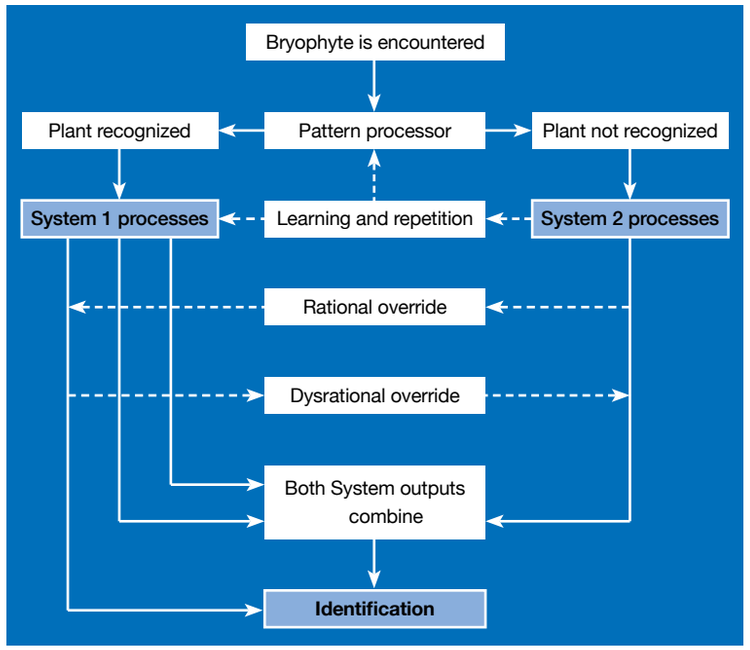
- *Outcome bias* – the tendency to prefer identifications that lead to the preferred outcome.
- *Overconfidence bias* – to maintain a positive self-image, we rate our abilities higher than they are and place too much faith in our own opinions.
- *Premature closure* – when a final identification is made before all the evidence has been assimilated.
- *Recency bias* – the tendency for a species to be judged more frequent than it really is just because it has been seen recently and comes to mind.
- *Retreat bias* – when a rare species is identified correctly, but we then retreat from it because of lack of confidence or many other reasons.
- *Search satisficing* – the tendency to stop looking for new features when something of apparent relevance is found.

▽ *Brachythecium glareosum* (left) and *B. rutabulum* (right). *J. Sleath*

Biases are not necessarily bad. Often they help us reach the correct decision quickly, and may have arisen in our evolutionary history to help us cope rapidly with changes in our environment.

System 2 is used when the plant is not immediately recognized and there are a number of possibilities to be considered in a systematic manner. It may involve collecting a specimen for examination under the microscope and subsequent keying out. It is slow, logical, has a low capacity and needs more effort and resources. Only one channel is processed at a time, and it develops through learning and experience. The bryological beginner over time learns how to identify plants and what features are important to reach a correct identification.

According to this model, both processes can be operating simultaneously and can influence one another. In the flowchart opposite, a plant is encountered and the immediate features are presented to a pattern processor. If pattern recognition takes place, System 1 processes are engaged automatically and a name is given



▷ Model for bryophyte identification based on the dual process theory. *Modified with permission from Croskerry (2009b)*

to the specimen instantly. This depends on previous System 2 learning, and the strength of the response depends on how well the salient features are present. Other System 1 processes may be triggered at the same time, for example the recognition that the plant is needed for the recording card. System 1 can fail here if the pattern has not been correctly recognized.

If the specimen is not immediately recognized, then System 2 processes engage and we go down a more analytic route by close examination of the plant, often using keys and other resources to reach a logical identification. There will be some System 1 processing taking place at the same time, for example the recognition of the genus, and so the final output of a System 2 processed identification will have some System 1 channels blended in. System 2 has a monitoring role over System 1 and can apply a 'rational override' to it if some features are not right. So a plant might look at first sight like *Brachythecium rutabulum*, but certain features do not fit, so the pattern processor triggers a System 2 response to override. A final identification of *Brachythecium glareosum* is made. *Conocephalum conicum* used to be identified by most of us using System 1 processes as it was instantly recognizable. When we became aware of the existence of *C. salebrosum*, System 2 started to function, providing a rational override. After learning and experience we have become better at separating the two plants and System 1 tends to dominate, although System 2 is still active. Sometimes this can happen too early and we can become overconfident with our identification.

System 2 monitoring enables us to be aware of and reflect on the process of identification, and often prevents a misidentification from taking place. Fatigue, distraction and indolence can all reduce the effectiveness of System 2 monitoring, as at the end of a long day in the field or a long microscope session. System 1 processing can

also apply a 'dysrational override' to System 2, particularly under these adverse conditions or the pressure of time, which is more likely to lead to an incorrect identification. The system has a tendency to default to whatever requires the least mental effort. This is also often where biases creep in.

Whilst no simple model can accurately reflect the complexity of human thought processes, I think this is a useful way of looking at how we approach identification. An awareness of the biases to which we are all vulnerable can help us to force ourselves to consider alternatives. Tools such as the *Field Guide* can help us to reduce our reliance on fallible memory with little extra cognitive effort. Being aware of what system we are using, and what the potential sources of error and bias are, should help us to be more aware of when and how we might end up with the wrong answer. A little less egg on my face from time to would not go amiss.

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△ *Conocephalum salebrosum* and *C. conicum*. *J. Sleath*

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