Working Memory and Cognitive Evolution in *Homo sapiens*: A Comparative Psychological Analysis of Contemporary Findings

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Charles Darwin's theory of evolution via natural selection has radically altered the scientific study of human cognition in the time since its introduction and acceptance. Once it became clear that the origin of *Homo sapiens* lay in creatures remarkably similar to nonhuman primates existing today, scientists began to look to these "living ancestors" of man in order to better understand our own evolutionary origins. And we have been rewarded for our efforts. The study of nonhuman primates has provided the scientific community with a wealth of information on primate biology, anatomy, and psychology. And because of the common evolutionary backgrounds of primates and humans, these findings can be used to understand more than just the way that humans once *were*; if examined properly, they can shed light on who we are *today*.

But how similar are we, really? Do primates truly exhibit enough parallels to modern humans that these kinds of evolutionary inferences can be trusted? The field of comparative psychology is devoted to answering this question. By testing humans and nonhuman primates under similar experimental conditions, comparative psychologists hope to firmly establish the psychological similarities between us and our close evolutionary relatives. One area that is of particular interest to comparative psychologists is the extent of evolutionary similarity in working memory abilities between humans and nonhuman primates. In addition to being a relatively simple aspect of primate memory to study (compared with long-term memory, for example), the testing of working memory capability provides insight to the similarities in the short-term reasoning capabilities of primates and humans. By determining how humans and nonhuman primates utilize working memory, we can expand our knowledge of how early hominids might have made decisions based on short-term memory, thus achieving a better understanding of the cognitive traits that helped our ancestors to survive.

Working memory

In order to fully understand the comparative significance of working memory in humans and primates, it is important that we first try to understand as fully as possible the nature of working memory itself. Wagar and Dixon (2004) conducted an experiment designed to test a possible component of working memory that, until their efforts, had not been investigated. Pre-existing theories concerning working memory state that visual information is stored in working memory using two separate classification mechanisms: a feature-based mechanism (which focuses on the number of features in an object) and an object-based mechanism (which focuses on the total number of objects being observed). It is generally agreed that, with these two mechanisms working in tandem, human working memory is limited to about four "items" total [3]. However, no study had previously examined the possible effects that past experience might have on object representation in working memory. Wagar and Dixon (2004) sought to further expand the current understanding of working memory by examining this possible connection between working memory and long-term experience.

Previous research with humans and non-human primates has suggested that, when told what features are important for category membership, those diagnostic features become more salient than non-diagnostic features during recall [3]. Wagner and Dixon (2004) attempted to reproduce these findings in an experiment specifically designed to test this possible influence on working memory. The experiment consisted of seventy-two undergraduate students who were divided into two groups. The first group was instructed to categorize 16 Greebles (photorealistic 3-dimensional objects displayed on a computer screen) into four different families, while the second group did not. All participants then completed a working memory task with the Greebles while simultaneously performing another task that involved either a verbal load or a visual load [3]. The goal behind this structure was twofold: firstly, the presentation of both visual and verbal loads tested whether object representation in working memory relies on visual representation (a concurrent task involving a visual load would thus hamper performance). Secondly and more importantly, if object representation in working memory has the sort of diagnosticity effect seen in previous studies, then the participants with prior experience examining the features of Greebles should show a marked improvement in recall of previously-searched-for features.

The results of the experiment yielded data that resoundingly supported the researcher's hypotheses. Not only did participants presented with a visual sorting task show marked impairment (thus indicating a significant visual component to working memory), but participants given previous categorization experience were significantly more successful at recalling previously-searched-for features than new features [3]. This finding is significant in that it supports the previous studies' claims to the same effect and expands our understanding of working memory as a whole.

Working Memory and Comparative Psychology

Experiments like the one performed by Wagar and Dixon (2004) have provided a tremendous contribution to our understanding of working memory in humans. And it is because of such work that comparative psychologists are able to attain a sufficient understanding of human cognition to be able to make reasonable predictions and form accurate hypotheses about possible evolutionary similarities between *Homo sapiens* and non-human primates.

Building on the studies of Sands and Wright (1980), Swartz *et al*. (2007) showed that monkeys and humans demonstrate similarities in problem-solving strategies when presented with serial probe recognition tasks. Encouraged by these results, Swartz created a modified version of this study that was specifically suited for orangutans. Swartz sought to reproduce in orangutans the kinds of problem-solving organizational strategies found to be used by humans when confronted with a working memory task [2]. The experiment consisted of a touch-screen monitor on which images of various objects were presented one by one, with a total of four to seven items being displayed sequentially, depending on the difficulty of the particular test. Once all items had been displayed, they were all shown simultaneously on-screen in random locations, with an assortment of other, non-test-related objects. The orangutans then had to select each item that had been displayed in the previous phase of the experiment, choosing them in whatever order the orangutans wished [2]. The goal of this was to see whether, like humans, the orangutans would reduce the load on working memory by organizing the items to be selected into subjective groups of similar objects. If the order of their selections was consistent through multiple tests, it could be concluded that the orangutans were, in fact, using a subjective organizational strategy.

The results, however, were surprising. Although the orangutans' accuracy was indeed above random chance, there did not appear to be any subjective pattern to their selections. After further examination, it was discovered that, instead of a subjective organizational strategy, both orangutans had implemented a right-to-left spatial organizational strategy on all tests involving more than four items. This finding was significant because, while it showed that orangutans might not utilize the *same* workload-reducing organizational strategy as humans, they began implementing such a strategy at the *same time* that humans typically begin implementing workload-reducing techniques: around 4 to 5 "items" in working memory. Thus, despite failing to find the primate-human parallel that they had hoped to find, Swartz and her colleagues discovered a common working memory limit among humans and orangutans – a significant finding all on its own [2].

Comparative psychologists have shown that it is possible to draw conclusions about the nature of primate working memory from experiments involving human participants. But the reverse has also proven true: just as studies on humans can be used as a basis for discoveries about primate working memory, so too have results taken from primate studies proven to be a useful tool in understanding the working memory of *Homo sapiens*. Gruber and von Cramon (2000) used previous studies on the prefrontal cortex of non-human primates to create an experiment designed to expand our understanding of working memory in humans [1].

Invasive techniques previously used on primates revealed that the primate prefrontal cortex (PFC) is parcellated into subregions that process different kinds of information, in particular spatial or object information [1]. Among these subregions was found a region specifically devoted to the processing of visual working memory. While this region was known to exist in humans as well, fMRI scans indicated that this region had been diminished in humans, thanks to an anatomical displacement that occurred after the evolution of language. Gruber and von Cramon (2000) hypothesized that if they could suppress this language-specialized portion of the human brain, then participants would be forced to once again rely on the same sorts of visual storage mechanisms found in primate working memory, and would consequently utilize the same portion of the brain found to be used by primates.

Participants were trained to perform item-recognition tasks involving colored letters while being scanned via fMRI. The letters were presented in blocks of four, with each letter having a randomized color and font. In between each presentation, a 4-second delay followed during which an audible tone was played. The tone was played in one-second pulses for the four seconds, with the intention being to suppress articulatory expression of the information to be memorized (in other words, the tone served to discourage the participants from simply reciting the letters to themselves). The subjects were instructed which of the features of the four target letters should be memorized during the delay. Afterwards, the subjects were told to press a button if a presented letter matched the features of one of the memorized items [1].

Analysis of fMRI data revealed that, when presented with a working memory task while under articulatory suppression, human subjects did indeed show an increased usage of the visual memory region of the PFC found to be used by primates presented with a similar task. This finding confirmed Gruber and von Cramon's proposed connection between human and primate working memory, and provides another example of how successful psychological comparisons can be made between humans and primates thanks to our common evolutionary ancestry.

Research in the areas of working memory and comparative psychology has shown that the evolutionary similarities between humans and non-human primates are in many cases strong enough that discoveries made about one group can safely be used to achieve a general understanding of the same processes in the other. Thanks to an expanded understanding of the common evolutionary ancestry of primates and *Homo sapiens*, we now have the ability to understand not only the psychology of modern man, but of early hominids as well. By understanding our primate relatives, we can better understand ourselves.

References

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