The Baldwin Effect, Genetic Assimilation and Social Learning

BY NAM LE

In 1896, the idea that learning can influence the evolutionary process was proposed by both Baldwin [1] (published in Nature Magazine) and Lloyd-Morgan [2] (published in Science Magazine), this was later named "The Baldwin Effect" by George Simpson in 1953 [3]. In the Baldwin Effect, the idea is an animal learns some skills, which later become innate or partially innate.

This superficially sounds Lamarckian but still can fit into a Darwinian framework. What is learnt in one generation is not passed directly onto the gene of the next generation. The Baldwin Effect works another way. Learning a new behaviour may provide adaptive advantage when the environment changes, modifying the evolutionary pathway of the organism. Learning generally involves cost. It is the cost of learning that generates selective pressure favouring individuals who can learn with minimum cost compared to others. If the environment is stable enough over a period of time, future evolution will favour learning that behaviour more quickly... and quickly to the point that the behaviour, or part of it, would be encoded in the gene pool. A similar idea was called Genetic Assimilation, proposed by the British biologist Conrad Hal Waddington [4] in his experiments to study epigenetics with drosophila. In general, genetic assimilation can be considered a sub-process through which the Baldwin Effect happens [5]

It is interesting that the idea of the Baldwin Effect was first discussed over 100 years ago, and then neglected for many years in mainstream biology, and even psychology, research. It gradually gained more attention following the classic paper by the British cognitive and AI scientist Geoffrey Hinton in 1987, entitled "How Learning Can Guide Evolution" [5] in which a computer simulation demonstrating the Baldwin Effect through genetic assimilation was presented. Since then, the effect has been investigated by a number of studies, mostly through computer simulations and in the field called Artificial Life (or ALife) – an interdisciplinary venue that studies natural life, its processes, and its evolution by recreating life-like systems through computer simulations, robotics, or biochemistry.

Why should we be interested in the Baldwin Effect?

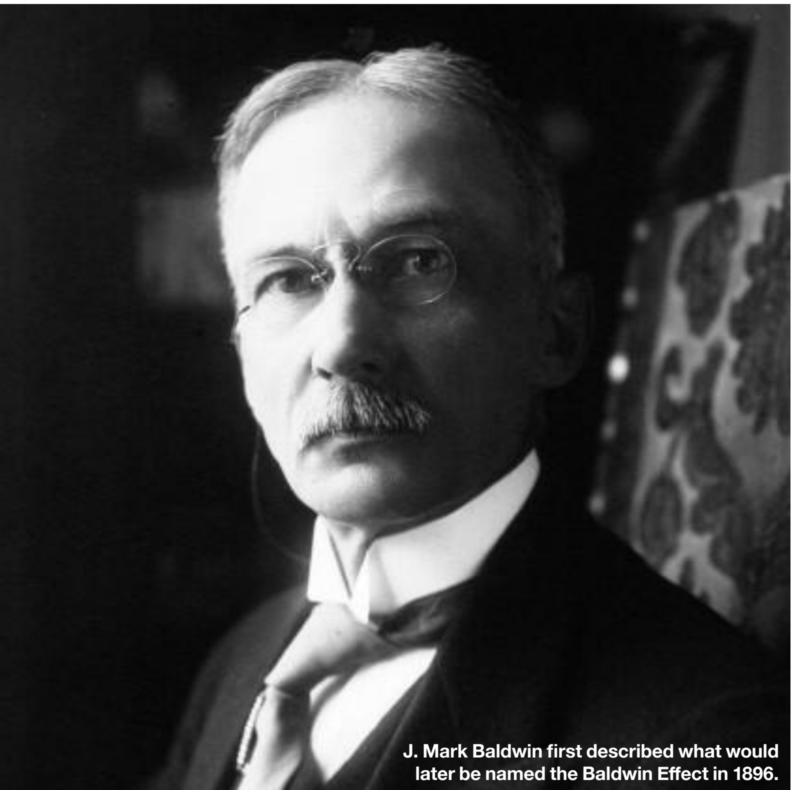
One plausible reason is that the effect, if happens, helps explain why and how evolution can be directed by intelligent faculties which are also the products of evolution. This stresses the importance of phenotypic plasticity, or norms of reaction, in evolution. This means there are circumstances in which the phenotype is not just the passive product of the gene and environment, but plays an active role in directing the evolutionary pathway of the species, through some forms of learning or niche construction [7].

Another reason, more interesting to me, for studying the Baldwin Effect is that it is how learnt behaviour can become innate, or genetically assimilated. This helps explain why environmental information can be encoded in the gene of different species. This is even more interesting in explaining the evolution of intelligent faculties in humans: For example, how the human brain evolved to learn and adopt complex cultural information, and how human language evolved and later became part of human instinct.

Why Social Learning Matters?

Learning generally can be broadly classified into two types, namely social learning and individual (asocial) learning. Individual, or asocial, learning can be simply understood as learning when the learner directly interacts with its environment, e.g., via trial-and-error, without the presence of others. Social learning has been observed in organisms as diverse as primates, birds, fruit flies, and especially humans [8]. By social learning, we mean learning that is influenced by observation of or interaction with another animal, or its products. Although the use of social learning is widespread in many animal taxa, understanding when and how individuals learn from others is a significant challenge. Social learning is generally less time-consuming than individual learning, but relies on information produced by others. When the environment changes, information gained from others is likely to be outdated and socially-learnt information can become maladaptive (not adaptive). On the other hand, asocial learning through trial-and-error is costly, but capable of producing new information which is particularly valuable when the environment happens to change.

Most work studying the Baldwin Effect focuses on individual learning by trial-and-error [5], [11].


J. Mark Baldwin first described what would later be named the Baldwin Effect in 1896.

When social learning comes in, the story would be more interesting as to how the Baldwin Effect occurs. Assume that one adaptive behaviour is found in the population, if social learning is permitted it will propagate that adaptive behaviour through the population very quickly. Some questions can be asked as to whether that behaviour, or part of it, could become innate in future generations? More interestingly, it is the cost of learning that triggers genetic assimilation of learnt behaviour. If the cost of social learning is less than that of individual learning, what would genetic assimilation look like in the presence of social learning? Which type of learning triggers more genetic assimilation?

If social learning is said to be a form of information-parasitism, social learning can only transmit behaviour if it exists, whether it was learnt via asocial learning or produced by genetic recombination. Before the Baldwin Effect can occur via social learning, the adaptive behaviour, which is expected to be assimilated, must be preserved in the population over generations. Nevertheless, if the cost of social learning is less than asocial learning, social learning will be favoured by natural selection more than asocial learning. There have been quite a few studies showing that if too much social learning is used, a population can become maladaptive as asocial learning gradually vanishes and there is no way to seek for a novel adaptive behaviour as the environment changes [9].

Here I posit that it would be very interesting to investigate the Baldwin Effect through the prism of social learning, or more precisely, through the lens of learning strategies – the combination of asocial and social learning in some manner, probabilistic or deterministic. Recent works via computer simulations say that a learning strategy can also result in the Baldwin Effect. In [6], each learning agent adopts a simple strategy is implemented as follows: Learn socially when the demonstrator is still adaptive, otherwise learn individually. When social learning is less costly than asocial learning, the above learning strategy was shown to trigger genetic assimilation more slowly and preserve more plasticity than asocial learning [6]. It is interesting to see that the Baldwin Effect through social learning favours the gene to learn an adaptive behaviour, rather than the gene to encode part of that adaptive behaviour, which is what has been found with asocial learning [5]. This has the obvious effect that the population with more plasticity will be more adaptive when the environment changes in the future. In similar studies it was shown that if social learning is much less costly than asocial learning, and if there is no rule governing each learning agent to learn strategically, then the Baldwin Effect cannot occur as asocial learning is gradually replaced by social learning over generations. Therefore the population has no way to preserve the adaptive behaviour until the Baldwin Effect would be able to occur [10]. The population with more plasticity will be likely to have higher average fitness in the future.

What has been shown so far informs us that there exists a scenario, with the presence of social learning, in which the Baldwin Effect occurs differently from the canonical genetic assimilation process, promoting more plasticity to facilitate future learning. This finding is, of course, domain specific since the fitness landscape used in [6] and [10] is quite extreme - a “Needle-in-a-haystack” - the landscape in which there is only one correct, or adaptive behaviour, and all the others are maladaptive. I would like to see if this finding can be generalised into different domains, and even more complex environmental scenarios. If the same or similar observation can be made, this could contribute to the explanation of behavioural repertoires and the evolution of intelligent faculties in humans. If the Baldwin Effect occurs through human cultural niche construction processes [7], this can help explain how the human brain evolved to be better at learning in the changing cultural world, and more intelligent human agents are more plastic agents rather than those with much genetic control.

The computer simulation in [6] though simple, can be considered a computer model in which three adaptive systems, namely evolution, learning, and culture, are allowed to interact with each other. Learning, both asocial and social, is the medium to trigger the gene-culture coevolutionary process, and the Baldwin Effect was presented as a way that cultural information can be encoded in the gene pool of the population. ALife simulations can be an interesting way to study social learning and cultural evolution. We also can take into account cognitive faculties when studying the evolution of learning and culture by including Artificial Neural Networks as a simple learning machine. Theory, mathematical modeling, and ALife approaches can benefit and complement each other in search of the understanding of social learning and culture, and the nature of knowledge in general. ❐

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