Thinking about Thinking in Objects: Methods, Findings and Implications from a Psychological Perspective

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Abstract

Many Object Oriented (OO) developers argue that the concept of objects is so primal or innate to our thought processes and understanding of the world that it is a fundamental element in nearly every aspect of thought, and as such the OO paradigm is the most suitable approach to software development. This paper considers a number of questions from the psychological perspective, relating to how, when and why we think in objects. It attempts to do this by describing how psychologists' understanding and representation of when we perceive objects and their properties has been studied and interpreted at the earliest stages of human development. In doing this it highlights some different perspectives and related methods which have been used by the field of psychology when interpreting the results. We consider why we might think in objects from the evolutionary perspective and what evidence might exist that may increase our understanding. In conclusion we consider how these various perspectives and studies might be utilised in our understanding of programming comprehension.

1. Introduction

The view that the concept of objects is so fundamental to our thought processes and understanding of our world that it is a central element in nearly every aspect of thought, is often cited by proponents of the object oriented programming (OO) paradigm as the main underpinning as to why the OO paradigm is the most suitable approach to software development. As with many other often cited sound bites the truth behind these claims is far more complicated than at first it might seem. In fact the study of when and how we develop the ability to think in objects is still a point of much debate within the psychology community. As with many other fields in psychology this question has resulted in a variety of different methods, each of which has produced their own data and interpretations. Much of our learning is based on the development and refinement of a framework of appropriate categories or concepts that facilitate our ability to plan and interact with both the living and non-living world around us. Bruner et al (1967) defined concept learning as "the search for and listing of attributes that can be used to distinguish exemplars from non exemplars of various categories."

By associating properties with this set of related representations we are able to do something as simple as recognising our own parents to something as complex as piloting a plane. As such the concept of objects both animate and inanimate is a seminal component of both social and material human thought. At its very basic level the concept of objects can be viewed as the awareness that objects exist even when inaccessible to the senses. For a number of years psychologists have theorised and developed methods to ascertain at what stage a child first displays the ability to conceive of objects and their properties independent of their field of vision.

This paper will investigate the notion of object representation from the psychological perspective and describe how Piaget and other psychologists have researched the development of the concept of objects and object related thinking in children and adults. It will then review the various methods and related evidence that these studies have produced. In conclusion it will present a summary of the various perspectives as to when and how we develop the ability to think in objects. One question that will be discussed is whether our ability to think in objects is simply an innate ability or should more

appropriately be considered as a result of other social or environmental factors. In addition this paper will consider how existing studies on how we perceive objects might provide a deeper understanding of the various psychological perspectives relating to object cognition and might additionally serve to fuel new research perspectives within the programming comprehension community.

2. Background

One of the earliest and best-known psychologists to develop a method and associated theory which related to when we can first think in objects was Piaget. Piaget and Inhelder (1969) theorised that infants only developed the awareness that objects continued to exist once out of sight as a result of their experimentation and exploration of the world around them. To test his theory Piaget developed a longitudinal experiment based on a small toy and a piece of cloth. Once the child's attention was focused on the toy it was then placed under the cloth in direct view of the child so the toy was no longer observable. Piaget observed that at first even though the child was physically able to remove the cloth and recover the toy they did not do so. This test was repeated on a regular basis and at approximately age nine months the child would remove the cloth to retrieve the toy. He surmised that for the child the hidden object had ceased to exist once out of sight and that early infants had no concept of objects as we understand them but developed this concept after birth by interacting with their environment.

Since then psychologists have suggested that although Piaget's observations were correct the data produced by his experimental method had more to do with the child's physical coordination than their concept of objects. To overcome this factor a similar method was developed by Bower et al (1971) based on a moving train that only required the observation of the path of the child's direction of view. The child visually followed the progression of a toy train along a piece of track, part of which was hidden from view. Once the train entered the obscured section the child was observed to change its direction of view to the expected location of the train's exit. Bower's experiment seemed to provide evidence that children of only two months were capable of anticipating the reappearance of the train. This suggested that although the child could no longer observe the train it had both a concept of the object and its associated attribute or property of direction even when out of sight and at even this early stage an infant had already developed the concept of objects. Later similar observation by Bower however showed that even when the train was halted in full view the infant's gaze continued to move along the track thus seeming to reverse his findings.

Baillargeon et al (1985) developed a similar set of experiments based on a five month old child's eventual habituation to the normal interaction of objects and their later attention to a series of impossible object interactions. After a period of habituation the child showed an increased attention to events that were impossible given the location and physical properties of the objects. This seemed to suggest that the infant had enough knowledge of not only the objects but also their fundamental properties to be able to predict the expected interaction of these objects.

Studies by Meltzorf and Borton (1979) married both tactile and visual senses by allowing four week old babies to suck on teats with different textures, who were then shown two models of the different teat types. Although the babies were not allowed to inspect the teats they showed a clear visual preference for the model of the teat that they had previously been sucking. This seemed to suggest that not only were the babies able to retain a concept of the object which had been in their mouth but could correlate the two different representations of visual and tactile representations. A further innovative but simple method was devised by Hood and Williatts (1986) which was used on babies of five months. The baby was placed in a room and shown an object. The light was turned off and the child's behaviour was observed in complete darkness with the aid of an infrared camera. Even though the object was no longer visible the babies reached in the direction of where the toy had last been,

thus a concept of the object must have been retained even though there was no longer any sensory input to suggest its existence.

Each of these studies has provided valuable clues to the abilities of object representation displayed by very young infants. Although at first they seem to produce contradictory results it is probably more appropriate to view these apparent contradictions as a need to further refine our understanding of the infants' abilities to conceptualise objects. For example one consideration of the infantile concept of objects relates to the period of time or the persistence of the child's memory for a given object. One example is a study carried out by Harris (1973) that was based on an adaptation of a Piaget experiment but with the additional dependent variable of time between hiding the toy and the child being allowed to retrieve it. This study showed that the memory of the object was extremely fragile and was probably located in working memory as opposed to long term memory, but this developed for older children.

4. So when do we first think in objects?

It would be nice to simply provide a quantitive reply but the answer from the psychological viewpoint relates closely to what psychosocial perspective you listen to. The question above feeds into a broader debate than simply "When do we develop an understanding of objects?" The perspectives can be broadly categorised as Behaviourist, Nativist, Constructivism and Social Constructivism. If we take the Behaviourist perspective for instance, infants must learn the concept of objects based on the principles of conditioning, modelling and imitation as we all start with a blank slate in terms of cognition. It then does not follow that an infant at the earliest stages of childhood could have any pre-existing concept of objects other than from current sensory input. This does not account for many of the findings described above; for example the cited Meltzorf and Borton study suggests that babies not only have a concept of objects but that they also display a moderate degree of complexity. In its most extreme case the Behaviourist view is no longer a tenable position for a large number of psychologists.

Many of the more recent findings seem to support a shift to a more Nativist position that easily co-exists with an innate ability in newborn infants to have a predisposition to the concept of objects. However the predetermined ways and degrees in which this may develop after birth as a series of qualitative changes is possibly more contentious and as such requires further studies. As researchers such as Baillargeon have worked with younger and younger infants their studies show that the Piaget view that newborn infants have no innate abilities in this area seems to be less plausible.

The Constructivist position proposes that children have qualitatively distinct and different stages as part of their normal development and takes the position that infants develop knowledge by interacting with their environment. If there is room to accept an innate concept of objects and their properties at birth (not done so by Piaget) constructivism provides a possible middle ground that encompasses both sides of the nature/nurture debate. Methodologists seeking data to support this position will need to create better approaches to gaining knowledge of what an infant is thinking. This is not an easy task, as young infants have only a limited capacity for physical gesturing, and next to no verbal ability. Forde and Humphreys have argued that we construct different representations for living and non-living objects. For Social Constructivists it would come as no surprise that infants are born with certain innate abilities that instantly enable the child to conceptualise and recognise the existence of living objects, as these are a seminal component in its path of learning. As for the infant the role of other humans is the single paramount factor in its survival and understanding of the world.

5. Objects and emotions

Although not really an area that the average software architect wants to consider, how we actually perceive objects may have a close relation to our emotions. For example related work on memory impaired adults by Forde and Humphreys (1979) illustrate the non-simplistic nature of the concept of

objects by arguing that adult human's representations for living and non-living objects are both functionally and anatomically different. For example with living objects such as an animal or apple it is mainly the perceptual features, such as the presence and shape, which make them distinctive, whereas for non-living objects it is predominantly their functional characteristics we conceptualise and these occur both functionally and anatomically in different locations within our brain. In addition to the type of the object any associated emotional attachment may also have an effect.

6. Evolutionary psychology perspective

So if it is innate then why do we think in objects? Evolutionary psychologists apply Darwin's (1859) theory of natural selection to the human brain and make the overarching claim that human social and cognitive abilities that are directly related to survival or reproduction are like their physiological equivalents; a product of natural selection and common to all humans. As with classical evolutionary theory it often uses a reverse engineering approach, which begins by asking fundamental questions as to why humans have developed particular abilities or intellect, and then tries to answer these questions by using knowledge of ethnology and a process of induction. One such strand of research may answer why we have evolved to think in objects. Halverson (1992) considers cave paintings as a source of symbolic data; he believes that the surge in the cognitive capability of the Upper Paleolithic is related to the importance of conceptual thinking in the culture. He believes that early man's cave paintings provide important insights into this development in our thinking and that this art served to expand the conceptual thinking of its creators, by depicting generic versions of the animal types they encountered on a daily basis. The art demonstrates early man's ability to recognise these animals as distinct species types, thus showing the beginnings of categorisational thinking. The majority of the pictures were of large edible herbivores (food sources), suggesting that the images were used for the sharing of information regarding hunting practices. This could have created an evolutionary advantage over other groups as their shared knowledge could possibly have resulted in more effective hunting strategies. This perhaps could be considered the earliest evidence of humankind's ability to think in objects.

7. Abstract and specific object recognition

More recently and perhaps of particular interest to the programming community is a model of cognition that suggests we have at least two independent cognitive subsystems: "abstract" and "specific" that are utilised for object recognition (Marsolek, 1999). Experimental studies by Burgund and Marsolek (2000) have shown that the first, the "abstract" subsystem, uses a features-based processing strategy to store features that are common to different views of the same exemplar, as well as common to different exemplars in the same abstract category. The second, the "specific" subsystem, is shown to use a whole-based processing strategy to store whole objects in which the representations are specific to the distinctive novel view of a particular object as it appears during an initial encoding trial. Marsolek (1999) has demonstrated that these dissociable neural subsystems which underlie object recognition operate in parallel and not in sequence. In addition and interestingly Burgund and Marsolek (2000) has shown that the "specific" subsystem operates more effectively than the "abstract" subsystem in the right hemisphere and that the "abstract" subsystem operates more effectively than a specific subsystem in the left hemisphere.

8. Conclusion and possible future work

To date much of the way in which we have developed our understanding of the psychology of programming is by a form of reverse engineering. Reverse engineering can be viewed as a process of figuring out the design of a mechanism based on how that mechanism performs different tasks. So for example by observing how a programmer develops code we hope to gain an insight into the inner workings of the programmer's cognition. Another alternative approach is to consider existing work from other perspectives that may provide a lateral or alternative view. Although this may not at first

seem relevant this approach may serve to shift existing patterns of thought, away from well-established or entrenched thinking to new or unexpected ideas.

As with many papers on psychological issues there are often more questions produced than answers given. This final section considers some possible areas for further investigation which have, to my knowledge, not been considered or investigated by existing studies from the programmer cognition perspective. For example, as it seems that the processing of living and non-living objects occur both functionally and anatomically in different locations within our brain and that for non-living objects it is predominantly their functional characteristics which we conceptualise as opposed to the perceptual features such as shape, could this phenomenon be observable in how we comprehend code that contains living and non-living object types e.g. cars and employees? In a similar vein if the truth is that our emotional relationship to the class or object type can affect our cognition and perhaps our design decisions (not an area covered in most OO design texts), how from the software design perspective might this influence our construction of class inheritance hierarchies. The work on "abstract" and "specific" object recognition by Burgund and Marsolek (2000) is of interest and worth further investigation. One simple outcome to which programming comprehension researchers might become more sensitive is the recording of handedness for each participant involved in a study, as it may be entirely possible that there is a significant difference in terms of handedness in the programming community when compared to other professions. Similar work has been carried out for other occupation areas, for example studies on architecture students show more left-handed proportionately than right-handed architecture students successfully completed their programme.

In answering the question "What has this paper to say if anything about programming cognition?", it is my hope that this paper will serve both to inform and perhaps to enable the reader to consider some novel aspects of existing psychological research which may serve to widen and inform their overall understanding and perhaps even enable them to consider new approaches to their existing research even though they may not at first seem directly related to programming cognition.

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