

# Study on the a not b error



After being discovered by Jean Piaget in 1954 perseveration tasks became one of the main means of investigation in cognitive development psychology, initially in children and later also in non-human animals. The most known of these is the, so called, A-not-B task, which even after many years of research still elicits debates about its underlying mechanisms. This paper aims to provide a review of existing empirical data in order to answer questions of who and why makes the A-not-B error. The first section of the review will give a theoretical background by describing the classic task used by Piaget, the importance of such experiments. This will provide a clear picture of what the A-not-B error is. The two following parts will focus on the questions of who makes the error and why, by an analysis of a set of classic experiments. Each study will be analyzed in terms of its goals, results, and what the impact of these findings is. The last part will include general conclusions based on studies analyses from previous parts. In order to answer the questions stated in the review title, “ what is the A-not-B error, who makes it, and why?”, classic data will be analyzed in order to determine what the best candidates for explanation of the mechanisms responsible for the error are (in the classic A-not-B task). The most convincing hypothesis will be chosen based on its explanatory power (can it explain most of the existing data?) and its relation to other approaches (can it incorporate other ideas?).

Publication of the book “ The Construction of Reality in the Child” in 1954 marks the beginning of research on perseverative tasks in infants. The author, Jean Piaget, described many hide and seek games, invented in order to investigate the understanding of permanence of objects in infants and its

changes in time. One of these games became one of the most widely used to explore infant cognition, the A-not-B task. The classic example of its procedure involved a 9 and a half month old child called Laurent. Piaget placed him on a sofa and presented him with two hiding covers, one on the right, and one on the left. Then, he placed his watch under the cover A, and observed Laurent lift the cover to retrieve the watch. After this hiding and seeking was repeated several times, Piaget hid his watch under the cover B. Laurent watched this action attentively, but when given a choice searched back at the location A. As the author put it, “ at the moment the watch has disappeared under the garment B, he [Laurent] turns back toward coverlet A, and searches for the object under the screen”. From this wrong choice, Piaget concluded that Laurent did not understand the independence of objects from his own actions on them. Since these initial results, the A-not-B error has been continuously studied and proven to be a strong and universal phenomenon in human infancy. However, the underlying mechanisms are still being debated, why the error happens and what it means. What is clearer, are the crucial elements of the task to produce the A-not-B error (Smith, 1999). In the original procedure an infant sits in front of two hiding locations that are highly similar and separated by a small distance. While the infant watches, an attractive object (for example a toy) is hidden in one of the locations, described as A. After a delay (which can vary), the infant is allowed to search for the object by reaching to one of the two hiding locations. This hiding and seeking is repeated several times, after which the object is hidden again, but this time in location B. Again, after a delay the infant searches for the object. In this traditional method, 8 to 10 month old infants keep reaching back to the initial location A, thus making the A-not-B

error. More recent data suggests that there might be also other important elements of the experiment, including posture of an infant, social context, or who the person interacting with subjects is. Before proceeding to a more detailed analysis of existing A-not-B task data, the significance of such research will be briefly described.

Investigations of A-not-B task are important for a couple of reasons. Firstly, it provides a clear paradigm to explore the development of infant cognition, how it changes in time. More specifically, it allows investigation how different processes involved in finding the object interact (such as looking, discriminating locations, posture control, and motor planning). Secondly, it also allows comparative experiments when the task is administered to nonhuman animals. Such research allow comparisons of cognitive abilities of different species and how these abilities might have evolved from common ancestors. However, after many years of research there is still no consensus on what is the meaning of the error and what its developmental importance is.

The question of what the A-not-B error is has already been answered. The next question is about who makes the error. An answer to this question will be approached by analyzing a selection of studies on the A-not-B tasks which investigated human infants (*Homo sapiens*), rhesus monkeys (*Macaca mulatta*), and dogs (*Canis lupus familiaris*).

The predominant group of participants checked on the A-not-B task are human infants of different ages. Diamond and Goldman-Rakic (1989) investigated extensively how the age of infants and the length of delay

between observing and searching influences the commitment rate of the error. The experimental procedure was based on the original task, designed by Piaget. However, several differences were also introduced. Instead of sitting freely, infants were held sitting on their parent's lap, prevented from turning or looking at the hiding location during the delay. Care was taken to ensure that the infant was observing the whole hiding process. In order to prevent visual fixation on correct hiding location, the infants were distracted by the experimenter calling them and counting aloud. Correct reaches were rewarded by gaining the hidden object (an attractive toy). In a case of an incorrect reach, the experimenter showed the right choice by uncovering the object, but did not allow the infant to reach for it. Testing for A-not-B began immediately after the infant first uncovered a hidden toy from one of the hiding places. Different lengths of delays between hiding and searching were introduced to the procedure to check what the crucial time to commit the error was. The first introduced delay was a 2 second one. Most infants below 8-8.5 months of age made the A-not-B error at these or smaller delays, whereas only one infant above 11 months did so. The second delay was 5 seconds. By 8.5 months only half of infants made the error at delays of 5 +/- 2 seconds. By 9.5 months half of the infants required delays greater than 5 seconds for the error to appear. The last experimental delay was 10 seconds, where no infant below 8.5 months had passed, whereas by 12 months the average delay needed to be longer than 10 seconds. An interesting observation from this experiment is that infants who maintained visual fixation on the correct hiding location also reached correctly, while those who shifted their gaze, failed to do so (performed at chance levels). Another interesting fact is that infants tried to correct themselves when they made

the A-not-B error (but not in the youngest ages). To sum up, the A-not-B error occurs in human infants at delays of 2-5 seconds at 7. 5-9 months, and at delays greater than 10 seconds after one year. These findings also are consistent with studies conducted by Gratch and Landers (1971) and Fox et al. (1979) which both found that infants of 8 months made the error at a delay of 3 seconds, as well as with a study by Millar and Watson (1979) which showed that infants of 6-8 months could avoid the error when there was no delay, but committed it with delays as brief as 3 seconds. This last finding corresponds closely with Diamond and Goldman-Rakic who found that infants of 8 months will succeed on A-not-B task if there is no delay, but that they will also fail at delays of 3 seconds.

Diamond and Goldman-Rakic used the same procedure to investigate ten rhesus monkeys with prefrontal lesions in comparison to monkeys with different brain lesions (parential), and ones with brains intact. Only animals with the prefrontal lesions committed the A-not-B errors at different delay lengths. There was no significant difference in performance between unoperated and parentially lesioned monkeys. Their age ranged from 2 to 6 years. At the delay of 2 seconds, all monkeys with prefrontal lesions committed the error. At the delay level of 5 second results were similar, all monkeys with prefrontal lesions committed the error. At the delay of 10 seconds the performance of prefrontal animals did not meet criteria for the error (such as at least one error in the reversed trial, the error at least once repeated during the same trial), exactly like human infants below 9 months. Behaviour of prefrontally damaged monkeys was noted to be very similar to that of human infants described before.

The last research analyzed in order to provide an answer to the question of who commits the A-not-B error was conducted by Topál et al. (2009) on dogs, wolves, and human infants. In a series of experiments a behavioural analogy between human infants and dogs was found. The goal of the research was to investigate the functional nature of dogs' sensitivity to communicative cues in a comparative framework, by the use of the A-not-B task. In one of the experiments dogs were shown to be influenced by the communicative context in their perseverative erroneous searches for hidden objects at a previously repeatedly baited (with a toy) location A, even when they observed the object being hidden at a different location (B). Such results are highly similar to those found in human infants. The task involved looking for a hidden object that the dogs saw being hidden behind one of two identical screens. The first phase consisted of the dog being allowed to repeatedly fetch the object (toy) from behind of the screens (location A). In the test phase, the experimenter hid the toy behind the alternative screen B. Dogs managed to fetch the hidden object correctly in all screen A trials. The main result from the test phase is that dogs in the social-communicative trial (the hider attracted the dog's attention) committed the A-not-B error more often than animals in the non-communicative (hiding with experimenter's back turned toward the dog) or non-social (experimenter stayed still while the object was moved between screen by another experimenter, not visible to the dog) version. Additionally, animals in the non-social condition were significantly more successful than chance during the test phases. To sum up, the error was eliminated when the hiding events were not accompanied by communicative signals from experimenters. Dogs were shown to be influenced by the communicative context in their perseverative erroneous

searches for hidden objects at the previously repeatedly baited location A, even when they observed the object being hidden at a different location B. Such results are highly similar to those found in human infants. Thus, the A-not-B error was proven to also exist in dogs.

Naturally this analysis does not exhaust all existing research on perseverative tasks. However, the aim of this review is to focus on A-not-B error only, in its classic version designed by Piaget. Other species, investigated in different variants of perseverative error tasks, included chimpanzees (*Pan troglodytes*), Japanese macaques (*Macaca fuscata*), cotton-top tamarin monkeys (*Saguinus oedipus*) (Hauser, 1999), as well as magpies (*Pica pica*) (Gómez, 2005).

After the data of who makes the A-not-B error was summarized, an analysis of the underlying mechanisms should follow, to answer the question of why the error is made. In literature different hypotheses are present. Principal of these include areas such as object permanence, memory deficits, information bias, immaturity of prefrontal cortex, and action oriented responses (reaching).

The first explanation was provided by the author of the A-not-B task himself, based on his initial research on perseverative errors. Piaget attributed this error to a lack of conception of object permanence in human infants. In his view infants commit the error because they do not understand that an object continues to exist even when out of sight. Their reach back to location A is therefore seen as an attempt to bring that object back to existence. This is the first, historical explanation, which has been disproved by various studies.



For example, Baillargeon (1987) has shown that some young infants (3.5-4.5 months) might have some understanding of object permanence. When watching possible (a screen rotating and stopping at a box behind it) and impossible events (a screen rotating as though there was no box behind it), infants looked longer at the impossible ones, which can be understood that they were not expecting them to happen. Similar results were also reported by Ahmed and Ruffman (1998), where infants who made the A-not-B error in search tasks looked significantly longer at impossible events than possible ones in a non-search version of the task. Such behaviours required a comprehension that when objects are out of sight, they continue to exist. Infants did not expect the object to be retrieved from a wrong place and therefore they had to understand in some sense where the object was actually located. Such results call into question Piaget's claims about the age at which object permanence emerges.

An alternative explanation focused on memory as a factor responsible for the error occurrence. In her research, Diamond (1985) found that different delay lengths between hiding and object searching affected the rate of the error. Thus the conclusion was that the recall memory was causing the A-not-B error. However, such view was challenged by Butterworth (1977), who found that use of transparent covers in hiding locations does not decrease the error rates, which is inconsistent with the recall hypothesis. Seeing an object underneath a cover should create no need of using the recall memory and lead to the error not being committed, which did not happen. This study also can be used to argue against the hypothesis that competition between different kinds of memory is responsible for the error. Harris (1989; after:

Ahmed & Ruffman, 1998) proposed that infants make the A-not-B error because of two memory traces in combination with poor attention. In this view, information about the object at location A is held in the long-term memory, whereas information about the object at new location B is kept in a weaker short-term memory. However, the fact that infants continue to make the error even when provided with clear cues of the object location (transparent covers), suggests that the underlying cause is not related to memory issues.

Another classic explanation placed the difficulty on the encoding of information. Bjork and Cummings (1984) suggested that encoding at new location B requires more processing (is more complex) than encoding repeated location A because B must be distinguished from A. Sophian and Wellman (1983) also referred to information selection, where prior information was mistakenly selected over the new information about location B because infants forgot current information (which relates strongly to the short-term memory limitations) or because infants did not know that current information should take over. These findings again can be debated in light of the transparent covers study by Butterworth (1977) and the violation-of-expectations study by Ahmed and Ruffman (1998). With the use of transparent covers, encoding new information does not pose major cognitive challenge since the desired object is visible all the time. The proposition of infants “not knowing which information should precede” is enough ambiguous in itself (what “know” means in this context, do adults “know” which information from their environment should be the most valid one?) and is additionally contradicted by the findings that infants look longer at

unexpected retrieval of objects from old locations. Therefore, they behave as though they “ know” where the object is currently hidden.

All of the hitherto presented hypotheses have met their nemesis data. At this point, two major explanations of the A-not-B error will be presented that yielded wider acceptance. One of them, supported by neuropsychological literature, is the importance of the prefrontal cortex, especially its relation with perseveration and inhibition. The prefrontal cortex is an anterior part of the frontal lobes of the brain, which is often associated with planning behaviours, decision making, and moderating social behaviour. As Hauser (1999) states it, the act of perseveration (a repeated production of particular action or thought) often represents the consequence of a particular cognitive problem, related to inhibition. In order to prevent perseveration such mechanism is required to reject some alternatives while favouring others, which may involve activation of the prefrontal cortex (Kimberg et al., 1997). Infants, therefore, are highly susceptible to the commitment of the A-not-B error because of their immature prefrontal cortex. The research by Diamond and Goldman-Rakic (1989) provided the first evidence that A-not-B performance depends upon the integrity of the prefrontal cortex and that maturation of this region underlies improvements in the task performance in human infants between 7.5 and 12 months of age. Further support comes from other groups of subjects of this study. Monkeys with lesions in the prefrontal cortex also committed the error, whereas monkeys with brains left intact, managed to choose the correct location B. As the authors noticed, the A-not-B task performance of operated monkeys and 7.5-9 month old human infants was highly comparable (both groups made errors at delays of 2-5

seconds). This significance of the prefrontal cortex can be explained by analyzing two main abilities required for the error to occur, which depend upon the dorsolateral prefrontal cortex: temporal separation and inhibition of dominant response (Diamond & Goldman-Rakic, 1989). The A-not-B task requires subjects to relate two temporally separate events: hiding cue and searching action. With no delay between hiding and searching even 7. 5-9 month old human infants and prefrontally operated monkeys can manage to choose the correct location B. However, even when a brief delay (2-5 seconds) is introduced, they start to fail in object searching. Therefore, the aspect of delay plays a crucial role in committing the A-not-B error. This disadvantage can be overcome when subjects are allowed to maintain visual fixation or body orientation towards the new location during the delay. A similar effect is created by a visible cue which consistently indicates the correct choice (for example a mark on one of the locations). Those two findings indicate a possible involvement of short and long-term memory in the process of committing the error. In the case of fixation on the correct choice, a representation of this choice does not have to be held in short-term memory, and in the case of learning an association between a landmark and a reward, the long-term memory is activated, guiding reaching behaviour accordingly. This brings back the argument about the role of memory in explaining the A-not-B error. The second ability stemming from the prefrontal cortex, the inhibition of dominant response, is mostly related to the act of reaching for the hidden object. In the A-not-B task subjects are first repeatedly awarded for reaching to location A, which leads to strengthening of this response. However, such conditioned tendency to reach to A must be inhibited in the test trial if the subject is to succeed and reach correctly to

new location B. The fact that subjects reach back to location A even when they appear to know where the object is hidden (by looking there) or should know where the object is placed (transparent covers with visible toys), adds validity to the notion that inhibiting the conditioned response is difficult and that memory might not play a major role in explaining the error (the problem is not simply forgetting location of an object). Even when the object is hidden, human infants and operated monkeys will often immediately correct themselves if their initial reach was incorrect. It appears therefore that subjects know the object is hidden in location B but still cannot inhibit the initial response of reaching to the previously rewarded location A. However, human infants often look in the direction of the correct hiding place, even when simultaneously reaching to the wrong one. It seems that the act of reaching itself might cause troubles, which relates to the next major explanation of the A-not-B error.

Smith et al. (1999) advocated a change in theoretical debates on possible explanations of the A-not-B error. Their explanation focuses on performance and behaviour during the task, which is described as reaching to successive locations in visual space. Errors are made by returning to an original location when the goal location had changed. Reaching to a place consists of a series of ordered steps, beginning with cognition (perceiving the target, forming a goal) and ending with action (selecting a motor pattern, forming a trajectory of the reach). The proposition states that the A-not-B error is mainly a reaching error, emerging from a directional bias to location A created by previous looking and reaching, and because the visual input available to guide the reaching hand is insufficient to overcome the bias (similar covers

close to each other, not fully developed reaching skills of 8 to 10 month old infants). Crucial to this hypothesis is the idea of a continuous interaction between looking, reaching, and memory of previous reaches. In other words, it is important that there are two similar potential reaching targets and that infants have a history of repeatedly reaching to one of the locations. Results from experiments by Smith et al. experiments indicated that goal-directed reaches of infants stem from complex interactions of visual input, direction of gaze, posture, and memory (therefore indicating strong context effects). Such a system is inclined towards perseveration since it creates the reach based on current visual input and memories of recent reaches. This bias will prevail whenever the new information input is highly similar to previous reach information or whenever the system's memory of previous reaches is strong. Such an effect could be described as a version of a previously analyzed information bias. These general processes of goal-directed reaching are not specific to a particular moment in development, which suggests that older children and even adults are prone to commit the A-not-B error if placed in the appropriate situation. For example, when no visual cues are given, like in the case of hiding objects in sand (Spencer et al., 1997; after: Smith et al., 1999). However, if these processes are not specific to a certain age, why then a decline in making the error is observed? Authors point to two developmental changes that can contribute to an answer: increasing infants' ability to discriminate among visually similar locations, and increasing skill in reaching. Although Smith et al. state that there is no discrepancy between their results and data from investigations of the role of the prefrontal cortex, they do not agree with the explanation placing emphasis on inhibition failure in this region of the brain. In such a view,

infants reach successfully to the correct location not because a dominant habit to reach to A was inhibited, but because the current visual information biasing the system in the B direction is stronger than the previously conditioned action towards A. Therefore, direction of the infant's reach depends on internal and external dynamics shaping the goal-directed action (outside stimuli and previous experience).

The goal of this review was to answer the questions of what the classic A-not-B error is, who makes it, and for what reasons. The answer to the first two is a straightforward one. In order to determine who makes the error, it is enough to administer the original procedure devised by Piaget to various subjects (with slight modifications if used with nonhuman animals). The question of why the error is committed has a more complex nature. A range of proposed explanations have been presented, along with an analysis of how valid these hypotheses are in light of existing empirical data. Due to limitations of space, the review has focused on presenting a summary of the main hypotheses: object permanence, memory deficits, information bias, immaturity of prefrontal cortex, and goal-oriented reaching. The two latter possess the largest explanatory power, as they incorporate or explain elements of other approaches. The most important difference between them is present in the definition of who can commit the error. In the neuropsychological approach only subjects with immature or a damaged neocortex will make the error, whereas in the reaching approach – this error is not so limited. Another main difference concerns the concept of inhibition. Described as a main element of the influence of the neocortex on choosing the right location, it is removed completely from the reaching approach.

However, certain similarities are also present, since the neuropsychological hypothesis includes the aspect of programming a goal-oriented reach. Considering these characteristics together, as the best candidate for an explanation of the A-not-B task the immaturity of the neocortex will be chosen. It can provide sufficient explanation for why human infants with immature prefrontal cortex, prefrontally damaged monkeys, and dogs make the error. In the case of the latter, the inhibition process might play the major part. Dogs committed the error mostly in the communicative experimental condition, which might suggest that overcoming a bias created that way is too difficult, inhibition in the prefrontal cortex (which is often assumed to organize social behaviour) is too weak. Of possible importance is the domestication process, during which dogs were selected to respond to human communicative signals. In terms of Marr's levels of explanation (Humphreys et al., 1994), the prefrontal cortex could be described as planning behaviours in order to act appropriately in the world (computational level), by the use of inhibition processes (algorithmic level) on the neuronal networks (implementational level). Additional empirical data, obtained in order to validate the prefrontal cortex hypothesis, should include studies on infant rhesus monkeys and other infant species, as well as autistic human children (due to their lack of social skills which could be attributed to malfunctioning prefrontal cortex). A set of such data would allow comparisons with existing findings. Naturally, new research might bring a change of focus in mechanisms underlying the A-not-B error, as the issue of perseverative errors is a complex one and requires further investigation.