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Review Article

The Optimism Bias: A cognitive neuroscience perspective

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Abstract. The optimism bias is a well-established psychological phenomenon. Its study has implications that are far reaching in fields as diverse as mental health and economic theory. With the emerging field of cognitive neuroscience and the advent of advanced neuroimaging techniques, it has been possible to investigate the neural basis of the optimism bias and to understand in which neurological conditions this natural bias fails. This review first defines the optimism bias, discusses its implications and reviews the literature that investigates its neural basis. Finally some potential pitfalls in experimental design are discussed.

Keywords Optimism bias - cognitive neuroscience - psychology - neural basis.

1 Introduction

Let us assume that John is a very poor student. He has not studied at all for his upcoming exam and has even sat a practice test which he failed. Despite all of this evidence, John believes that his chances of passing the upcoming exam are very high. Since his expectation is better than reality he is being unrealistically optimistic. John exhibits the optimism bias. This definition causes a problem for researchers who want to study the optimism bias. The experimenter cannot possibly have access to all of the variables that will affect John's exam result. Hence, it is virtually impossible for an experimenter to accurately quantify an individual's probability of experiencing a particular event (Weinstein, 1980).

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2 The Study of the Optimism Bias

One way for scientists to test the optimism bias in the laboratory is to ask an individual to predict his chances of experiencing an event and then following up to see whether the event transpired. The problem with this approach is that the outcome of an event does not always accurately represent the person's prior chances to attain that outcome; this is especially true when the outcome is a binary one. For example, we know that an individual has an infinitesimally small chance at winning the national lottery. If Peter predicts that he has a 75% chance of winning next week's lottery and then happens to win the lottery, this does not mean that Peter was actually pessimistic in his prediction. It simply means that he was very lucky, over and above being very optimistic.

While it is extremely difficult to tell whether an individual is being unrealistically optimistic, it is relatively easy to show that, as a group, people are unrealistically optimistic (Weinstein, 1980). If it can be shown that the majority of people in a group believe that they are superior to the majority of other people in that group, then it can be inferred that some of these people are unrealistically optimistic (Sharot et al., 2012; Weinstein, 1980). For example, (Svenson, 1981) showed that 88 percent of US drivers believe that they are safer drivers than the median driver. People were also shown to think that they were more likely than their colleagues to like their post-graduate job or to own their own home. At the same time participants thought that they were less likely than their colleagues to have a drinking problem or to attempt suicide (Weinstein, 1980). People also remain unrealistically optimistic about their own futures despite clear evidence that they should not be.

3 Psychological Mechanisms Underlying the Optimism Bias

Classical theories of learning suggest that if a person is given accurate information that contradicts their belief, then that person should subsequently update their expectations in a Bayesian manner (Pearce and Hall, 1980; Sharot, 2011). In a study set up by (Sharot, 2011), it was found that healthy individuals update their expectations in an asymmetrical way. If participants were given news that exceeded their expectations, they updated their future expectations according to the classical learning theory. However, if the news was worse than they expected they updated their future expectations slightly, but this did not reflect the extent of the news (cf. Eli and Rao 2011). An illustrative example given in the paper was that if a participant expected that his chances of getting cancer was 40% and was told that his actual likelihood was 30% then subsequently, the participant would probably decrease his expectations of cancer to about 31%. If, on the other hand he estimated his likelihood of getting cancer at 10% but was told that the true likelihood was 30%, he would subsequently not update his expectation to 30% but perhaps update it to about 14%. Evidence also shows that both younger and older individuals exhibit a greater asymmetry in belief updating. Hence, children and elderly individuals tend to have problems learning from bad news (Chowdhury et al., 2013; Moutsiana et al., 2013).

There is a group of individuals that do not show this bias. (Strunk et al., 2006) showed that dysphoric, or mildly depressed, individuals do not show any bias (optimistic or pessimistic). It is important to note that this does not necessarily mean that a dysphoric individual is always realistic, but that on average any biases they have cancel each other out. The authors also found that as a person becomes more depressed they are more likely to show a pessimistic bias.

As a result, experimenters have argued that healthy individuals have a tendency to be optimistically biased. This is in line with animal experiments that showed healthy, well treated animals to be optimistically biased whereas animals in poor environmental condition did not show the bias (Matheson et al., 2008). Traditionally, psychologists have maintained that a realistic outlook on life is the hallmark of mental health and wellbeing (Taylor and Brown, 1988). (Lazarus, 1983) started questioning this fundamental tenant of mental health. One could imagine a scenario were two cavemen, Peter and Max, are sitting in their cave and hear a rustle outside. This same sound could represent food, a little edible squirrel, or alternatively it could be a predator, the soft rustle of a lion's paws over leaves. In most situations it is a squirrel but occasionally it is a lion. Peter is optimistic

and goes out; Max is pessimistic and stays in. Which one is better off? In this case Peter got eaten by the Lion, but if Max never leaves the cave he will starve to death. (McKay and Dennett, 2009) argue that although misbeliefs in general are maladaptive for an organism, positive false beliefs, such as the optimism bias, are generally adaptive. In fact, there is an increasing amount of studies showing that people who exhibit moderate levels of unrealistic optimism are better off than counterparts who have no bias, a pessimistic bias or an excessively optimistic bias (Friedman et al., 1995; Puri and Robinson, 2007). For example, optimistic individuals are more likely to comply with medical treatment and attend follow-up appointments (Friedman et al., 1995; Scheier et al., 1989). (Varki, 2009) takes an extreme point of view and proposed that optimism is not only useful but is indeed essential for human beings to function properly and survive. He states that with the ability to prospect comes the knowledge that death awaits each and every one of us. He proposes that without an unrealistically optimistic outlook on life humans would be overcome by great fear that would essentially render us extinct. Hence, the optimism bias is adaptive and likely to have been evolutionarily preserved for two crucial reasons. First, despite being inaccurate in their predictions of future events, optimistic individuals are more likely to be motivated to improve their wellbeing. For example, if an individual thinks they are less likely than the average person to contract disease X they may actively find ways to ensure that they do not, thus the prediction becomes a self-fulfilling prophecy. Second, they are less likely to be overwhelmed by an existentialist crisis that could lead to suicide. The increase in the optimism bias in elderly individuals may be a mechanism for elderly individuals to cope with the increasing health problems that arise in old age (Chowdhury et al., 2013).

Although moderate unrealistic optimism can indeed be adaptive, excessive optimism has, on the other hand, been shown to be maladaptive. Collective unrealistic optimism has been, in part, blamed for some of the greatest economic follies of our time such as the economic bubbles (and their inevitable crash) (Johnson and Fowler, 2011). While moderate optimists are generally selective risk takers and make relatively good economic decisions, extreme optimists tend to make decisions that are generally considered to be unsound (Puri and Robinson, 2007). In fact, the increase in optimism in older age may be a double edged sword since although the higher optimism allows the elderly to cope with increasing health problems, it may also lead them to make poor financial decisions (Chowdhury et al., 2013).

4 The Neural Basis of the Optimism Bias

If this bias is found in most healthy individuals and has been evolutionarily selected for, then it is reasonable to assume that there is a neurological network that underpins it. (Sharot et al., 2007) published a pioneering paper on the neural basis of the optimism bias. Using functional MRI (fMRI), Sharot and colleagues demonstrated that the rostral anterior cingulate (rACC) and the amygdala showed enhanced activation when participants imagined positive future events. The authors suggest that the amygdala could be involved in the mental construction of future events that have a high emotional valence. It was also suggested that the rACC is involved in monitoring the subjective importance of a future event and it may reflect the brain's regulatory mechanism to steer the individual to select an optimistic outlook. The rACC was shown to be strongly functionally connected to the amygdala, suggesting an intercommunicating neural network underlying the bias for positive predictions. The authors also pointed out that these are the same regions abnormal in people who suffer from a depressive illness. The pessimistic bias shown in depressed patients may be due to a disruption of the above neural network. Although researchers have investigated functional brain networks there has been no research to date on the structural networks that underlie the functional networks. With the advent of advanced diffusion MRI tractography techniques, there is an opportunity for further research in understanding the brain network that underlies the optimism bias.

In their 2011 study, Sharot and colleagues also provide data on the neural mechanisms involved in maintaining optimism, in spite of evidence that one should not be optimistic. The authors suggested that the right inferior frontal gyrus (IFG) may be involved in monitoring negative information. Interestingly the right IFG of participants who scored low on trait optimism was better at monitoring negative information than in those participants who scored high on trait optimism. Conversely, the left IFG, the cerebellum, the left and right medial frontal cortex (MFC) and superior frontal gyrus (SFG) were involved in monitoring positive information. These areas did not show any difference in participants who scored high or low on trait optimism. The authors were able to predict the amount that a person would update his or her beliefs by looking at the reduction in BOLD activity in the right IFG. It was suggested that optimistic individuals have a reduced ability to neurally code aversive information. The authors of the study also suggest that the effect may be modulated by the participant's motivation to have the best future possible. The results were consistent with results in other

domains of neuroscience, where it was shown that these areas are associated with behavioural and reality monitoring (Brunamonti et al., 2014; Sugimori et al., 2014).

The next important step was to identify whether any of these regions are necessary for the optimism bias to be present. While fMRI is a correlational method, Transcranial Magnetic Stimulation (TMS) uses high field magnetic pulses to directly interfere with the electrical activity of a neural structure. If it can be shown that a disruption in one anatomical structure results in a change in the effect of the optimism bias, then there will be a strong claim that the neural structure is necessary in generating the neural process that produces the behavioural effect known as the optimism bias. Using TMS (Sharot et al., 2012) showed that a disruption of the left IFG improved the participant's ability to learn from bad news. Participants who had TMS stimulation on the left IFG updated their expectations even when they received bad news. TMS to the right IFG did not show this effect. It may seem contradictory that, while the fMRI study suggested that the right IFG was involved in monitoring negative information, it was TMS to the left IFG that showed a change in behaviour. This can be explained if the left IFG has an inhibitory role (Anderson et al., 2004; Aron et al., 2004). If TMS inhibits the proper functioning of the left IFG it may cause a disinhibition of the system, thus eliminating the bias. This paper has shown a proof of principle that the optimism bias can indeed be modulated by interfering with the body's hardware (or wetware).

Research has also shed light on the possible neurotransmitters that are involved in modulating the optimism bias. (Sharot et al., 2009) showed that participants who received L-DOPA expected more pleasure out of future events than participants who have not received the drug (Sharot et al., 2009). It was also shown in a later experiment that an increase in dopamine increases the optimism bias by impairing the participant's ability to learn from negative outcomes (Sharot et al., 2012). In fact, the optimism bias increased as a function of dopamine levels. This evidence is consistent with the results of (Frank et al., 2004) who showed that parkinsonian patients that were off dopamine enhancing medication can learn better from negative outcomes, while patients on their medication do better learning from positive outcomes. These studies provide a possible mechanistic explanation behind dopaminergic antidepressant drugs (Papakostas, 2006). In summary, the research of recent years has shown that the optimism bias is associated with frontal (IFG) and limbic (ACC and amygdala) brain networks. It suggests that the left IFG is important in the inhibition of updating expectations in response to bad news. Finally it has been shown that dopamine is an important modulatory neurotransmitter

in the system and that the availability of dopamine in the brain affects the extent of the optimism bias.

Although the scientific community has started to understand the brain basis of the optimism bias, further questions remain unanswered. For example, is there a particular sub region within the IFG that is more important for this effect than other areas? The cytoarchitecture of the IFG is not homogenous (it can be divided into Brodmann areas 44, 45 and 47). Furthermore, language research has shown a double dissociation within the left IFG, with the anterior region being involved in semantic processing while the posterior region is implicated in phonological processing (Buckner et al., 1995; Fiez, 1997; Gough et al., 2005). Presumably, the anterior and posterior aspects of the IFG are involved in different structural and functional networks. It would be interesting to see whether the optimism bias shows specificity to a particular location within the IFG. This line of research could improve our structural understanding of the networks involved in producing this bias. It will also be interesting to see whether patients who have structural damage (secondary to stroke) to particular areas show predictable deficits (or enhancements) in the optimism bias. Do people who have acquired aphasia due to a stroke in the left IFG show a reduced optimism bias? This information would be invaluable to practicing clinicians involved in the rehabilitations of these patients.

5 Criticisms and Caveats

Although the optimism bias has been studied extensively since the 1980s, there have been a few caveats raised in the literature that cast doubt on some experimental designs. (Harris and Hahn, 2011) argue that three types of statistical artefacts may make them seem to be unrealistically optimistic.

First, the authors show experiments that use discrete attenuated scales rather than continuous scales that can cause an appearance of optimism when there in fact is none. This is because attenuated scales, for example a scale from 1 to 5, does not allow for subtle differences to be reported by the participant. Hence, even if participants are realistic in their true estimates, an attenuated scale can make them appear unrealistically optimistic.

Second, due to minority undersampling, if an event is rare enough, the likelihood of finding people who know that they have a higher probability of experiencing that event is rare, thus, since the minority is underrepresented, our data will not show the true picture.

Finally, base rate regression is when people tend to overestimate the risk that an event will occur to the average person. Hence, an accurate prediction by the participant of an event happening to them may be interpreted as optimistic due to an overestimation of how probable that event is for other people.

These limitations are mainly present in experiments where groups of participants compare their risk to another group of individuals. For example, when on average people think that they are better drivers than the average driver. (Shepperd et al., 2013) argues that while these statistical limitations look worrisome, they should not cause undue concern. First, experiments using non attenuated scale have still showed evidence, albeit less dramatic, of the optimism bias. Second, minority undersampling is only a problem when investigating rare events and many experiments investigate relatively common events such as divorce, buying a nice house or getting a good job (Weinstein, 1980). However, even for these events, if many groups of people are examined, for example in a meta-analysis, minority undersampling disappears as a problem since the group will then be large enough to adequately represent rare events. Finally, experiments still showed evidence of the optimism bias when the base rate of an event was given, hence controlling for base rate regression.

Rather than disproving the optimism bias theory, the (Harris and Hahn, 2011) paper highlights potential pitfalls that any experimenter should keep in mind prior to designing their experiments.

6 Conclusion

In conclusion, the optimism bias is a well-established psychological phenomenon that, despite criticism, has been replicated in many experiments. While it is generally an adaptive phenomenon, it can have disastrous consequences (such as an economic collapse). Research has moved away from a description of the phenomenon onto trying to understand the underlying psychological and neural mechanisms that underpin it. This has led to investigation of ways of modulating this phenomenon. The translational potential of this research has already been recognised by some. Governments and institutions are, in certain cases, modifying plans to accommodate for it. For example, the budget for the 2012 London Olympics was modified to accommodate the optimism bias (House of Commons Committee of Public Accounts, 2008, p. 8; Sharot, 2012). This research has the potential to be translated from bench to bedside. It is providing a psychological and neuroscientific grounding for the treatment of depression. In a future where humans have the ability to remove or enhance an optimistic bias through pharmacological means or by TMS, the difficulty may be in recognising when the optimism bias is adaptive and when it is detrimental. Getting it wrong may, in itself, have disastrous consequences.

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