Trends in Cognitive Sciences

Review

Differences in Behavior and Brain Activity during Hypothetical and Real Choices

Colin Camerer[1,2,*] and Dean Mobbs[1,2,3]

Real behaviors are binding consequential commitments to a course of action, such as harming another person, buying an Apple watch, or fleeing from danger. Cognitive scientists are generally interested in the psychological and neural processes that cause such real behavior. However, for practical reasons, many scientific studies measure behavior using only hypothetical or imagined stimuli. Generalizing from such studies to real behavior implicitly assumes that the processes underlying the two types of behavior are similar. We review evidence of similarity and differences in hypothetical and real mental processes. In many cases, hypothetical choice tasks give an incomplete picture of brain circuitry that is active during real choice.

Trends

Many experiments in cognitive neuroscience use hypothetical choices, or use stimuli that lack some realistic features. The goal of the experiments, however, is to understand behavior and brain activity during real choices people make.

Hypothetical and limited-realism experiments run the risk of understating the strength of brain activities, or giving an incomplete picture of the neural mechanisms, which are evoked by real choices.

There is some evidence of differences in behavior and brain activity between hypothetical and real choice in domains of social, moral, and economic choice.

There are also differences in brain activity, between more or less realistic stimuli, in emotional reactions and in visual processing.

More studies directly comparing hypothetical and real choice are needed, as well as imaginative realistic paradigms.

Understanding How the Brain Makes Actual Choices

Social science seeks to understand the causes of the choices that people make which affect their lives. Isolating possible causes in artificial experiments is easier when an experiment is simple, but a simple design can always be criticized on the grounds that it is too simple to be realistic. One limit on realism is that experimental subjects often make hypothetical choices with no direct consequences to them (unlike in corresponding real decisions). There may be limits to how well hypothetical choice, and associated brain activity, approximates real choice and activity. There may be similar differences between brain and behavior when objects are presented more or less realistically (e.g., a 2D image compared with an actual object).

There are likely to be two types of differences between hypothetical and real behavior: differences in **naturalistic intensity** of stimuli (see Glossary), and differences in what neural mechanisms are used to make choices. Consider fear as an example (discussed further later). Seeing a 2D image of a tarantula is likely to provoke less intensely arousing emotion than seeing an actual tarantula crawling toward your foot; the crawling tarantula has more naturalistic intensity. That is, fearful emotion could be encoded in the same regions in the picture and actual conditions, but activity will be stronger and more widespread when the tarantula is real. In addition, the actual tarantula getting closer to your foot is likely to activate specialized neural circuitry (e.g., motor preparation for movement, and ancient evolutionarily conserved survival regions such as periaqueductal gray). Another example, also previewing studies discussed in the following section, is that overlapping value regions are active, whether choices are either hypothetical or real, during charitable giving and paying to avoid eating unpleasant food. However, the amygdala is only active during those choices in the real condition.

[1]Computation and Neural Systems Program, California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91125, USA
[2]Department of Humanities and Social Sciences, California Institute of Technology, 1200 East California Boulevard, Pasadena, CA 91125, USA
[3]Department of Psychology, Columbia University, 370 Schermerhorn Hall,

 http://dx.doi.org/10.1016/j.tics.2016.11.001

We evaluate evidence of differences in hypothetical and real behavior and brain activity in five domains: sociality, morality, emotion, economic choice, and vision. In almost all cases, there are substantial differences in behavior and brain based on the realism of stimuli (in vision) or on whether choices have actual consequences, such as financial reward, receiving shocks, buying consumer products, or eating unpleasant food.

1190 Amsterdam Avenue, New York, NY 10027, USA

*Correspondence:
camerer@caltech.edu (C. Camerer).

Social Neuroscience

Social neuroscience is a relatively new field that integrates concepts from social psychology and methods from cognitive neuroscience. To date, there has been little work comparing hypothetical and real choice, but interesting work has attempted to increase the degree of realism in the form of true live interaction between multiple subjects. Social neuroscientists have studied interactions when one subject is inside an MRI scanner, and is making choices that can be influenced by interaction with one or more subjects who are outside of the scanner. Various experiments have studied empathy [1], social distance [2], social approval [3], moral behavior [4], and advice giving [5], with each pointing to new insights into the social brain. While these paradigms overcome the problems of passive observation of social stimuli (e.g., observing a face), they are not truly interactive because they reflect only the one-directional 1D outcome of one's own behavior on another person (sometimes called **'spectatorial approaches'** [6] because subjects merely observe other people or contemplate the others' mental states). A **'two-directional'** approach, using real-time social encounters in which all subjects make choices that influence each other's rewards, is an important step forward [7] (see Outstanding Questions).

Two-directional interactive approaches have been used in several studies. Two pioneering studies used simultaneous fMRI 'hyperscanning' of two subjects playing a financial game requiring economic trust [7,8]. One subject chooses how much money to invest, which triples in value; a second subject then chooses how much of that sum to share (and can keep it all) [9]. Hyperscanning was also used to study formation of 'bubbles' – price paths that grow unrealistically high and then crash. In these experimental markets, subjects chose the prices at which they trade with each other [10]. In two hyperscanning studies on bargaining, one subject first chose to say how much they would pay to buy an object, and the second subject chose whether to sell the object at that price or not [11,12]. Amygdala activity was associated with suspicion that the first subject was 'lowballing', understating what she could really pay.

Another design [13] used live interaction between a subject being scanned and subjects outside of the scanner, while the subjects engaged in social interaction and joint attention tasks. During live social interactions, compared with recorded ones, there was more activity in many cortical mentalizing regions, including the posterior superior temporal sulcus, temporoparietal junction, and medial prefrontal cortex (mPFC). The posterior superior temporal sulcus was more active during joint compared to solo attention, supporting the idea that this region is involved in social attention.

In the 'pragmatics' approach to language, speech acts are viewed as choices intended to solve a joint action problem. Although not interactive, studies have used intersubject correlations to examine the coordination of natural speech and speech comprehension by motor, linguistic, and extralinguistic speech production systems [14,15]. In these studies, subjects are either speakers and listeners. Speakers are trained to precisely reproduce a 15-min long narrative. There was a robust coupling of time-locked neural activity between speaker and listener. When speaker–listener communication failed, this neural coupling disappeared. This realistic speaker–listener coordination also found overlapping neural activity that was bilateral and more widely neurally distributed than has been observed in less lifelike tasks (which typically only show speech and comprehension overlap reliably in left hemisphere language areas). In other words, brain scanning during less realistic speech tasks gives an incomplete picture.