Audiovisual perception

Implicit estimation of sound-arrival time

In perceiving the sound produced by the movement of a visible object, the brain coordinates the auditory and visual inputs so that no delay is noticed even though the sound arrives later (for distant source objects, such as aircraft or fireworks displays, this is less effective). Here we show that coordination occurs because the brain uses information about distance that is supplied by the visual system to calibrate simultaneity. Our findings indicate that auditory and visual inputs are coordinated not because the brain has a wide temporal window for auditory integration, as was previously thought, but because the brain actively changes the temporal location of the window depending on the distance of the visible sound source.

Seven subjects with normal vision and hearing were presented through headphones with a burst of white noise (90 decibels sound-pressure level, 10-ms duration, with 4-ms rise and fall times), the spectrum of which had been processed (by using head-related transfer functions) to simulate an external sound from a frontal direction. Brief light flashes (10 ms) were produced by an array of five green light-emitting diodes (LEDs) at different distances from the subjects (1–50 m; Fig. 1). The intensity of the light flash was 14.5 candelas per square metre at a viewing distance of 1 m, and was increased in proportion to the square of the viewing distance for the other distances in order to produce consistent intensity at the eye. The difference in onset times between the sound and light stimuli was varied randomly from −125 ms to 175 ms in steps of 25 ms.

Subjects were instructed to look at the centre of the LED array and to imagine that the LEDs were the source of both light and sound, while listening to the sound directly from the sound source. To eliminate possible bias effects, we used a two-alternative forced-choice task to measure subjective simultaneity: in this task, observers judged whether the light was presented before or after the sound. Twenty responses were obtained for each condition. To determine the stimulus-onset asynchrony that corresponded to subjective simultaneity, we estimated the 50% point (the point of subjective equality) by fitting a cumulative normal-distribution function to each individual’s data using a maximum-likelihood curve-fitting technique.

When the LED array was 1 m away, the point of subjective equality occurred at a sound delay of about 5 ms; however, the sound delay at this point increased with viewing distance (P < 0.001; Fig. 1a, b). This increased delay was roughly consistent with the velocity of sound (about 1 m per 3 ms at sea level and room temperature), so the point of subjective equality increased by about 3 ms with each 1-m increase in distance. This relationship was consistent at least up to a distance of 10 m.

Our results show that the brain probably takes sound velocity into account when judging simultaneity. However, it takes about 120 ms for sound to travel 40 m, and we found that the threshold for detecting the sound delay was 106 ms at a viewing distance of 40 m, so active compensation is likely to operate only for shorter distances than this.

We have shown that the brain takes sound velocity into account when integrating audiovisual information. The brain can therefore integrate audiovisual information over a wide range of temporal gaps, and correctly match sound and visual sources.

Yoichi Sugita*, Yôiti Suzuki†
National Institute of Advanced Industrial Science and Technology, Neuroscience Research Institute, Tsukuba 300-420L, Japan
*e-mail: y.sugita@aist.go.jp
†Research Institute of Electrical Communication and Graduate School of Information Sciences, Tohoku University, Katahira, Aoba-ku, Sendai 980-8577, Japan


Competing financial interests: declared none.

brief communications

Sociology

The puzzle of human cooperation

Humans often defy rational-choice theory by cooperating in simple dilemma games, a paradox that has been explained by theories of kin selection, reciprocal altruism and indirect reciprocity (reputation). Fehr and Gächter claim that human cooperation remains an evolutionary puzzle because people will cooperate with genetically unrelated strangers, often in large groups, with people whom they may not meet again, and without any gain in reputation (‘strong reciprocity’)—that is, when existing theories do not seem to apply. However, we argue that those theories are rejected for the wrong reasons and that the paradox may therefore be imaginary. This has implications for whether punishment is crucial to promoting cooperation.

First, strong reciprocity is not necessarily a puzzle because altruistic tendencies need not reflect contemporary selective pressures. Rather, they may reflect motivations that evolved during the past 5–7 million years, in situations that were very different from those presupposed in the puzzle (small groups with relatedness greater than random, individuals well known to each other, interactions likely to be repeated, and people organized in hierarchies). The puzzle disappears if human brains apply ancient tendencies to cooperate that persist in newer environments, even if they are maladaptive (heuristic rules that violate expected utility often make sense for common tasks in our evolutionary history).

Accordingly, kin selection, reciprocal altruism and indirect reciprocity need not explain why altruism fails to conform to rationality theory today; rather, they explain why it became ingrained in our brains in the past. Today, humans distinguish and favour kin, or select partners with whom to repeat games, but this does not conflict with those explanations (it supports their legacy in our evolution). The cost of errors may be high but they are recent, so it is unclear whether selection has been strong (or fast) enough to realign humans’ strategic behaviour specifically to deal with modern problems—evidence for systematic deviation from rational solutions indicates that it has not. Such deviations occur across cultures, suggesting an ancient and/or common
brief communications

origin, rather than a fine-tuning to varied modern circumstances. Second, the punishers in laboratory experiments such as Fehr and Gächter's are anonymous\(^1\), so potential extra costs resulting from retaliation (of any sort) by victims are ruled out. Anonymity is unrealistic among early human groups: vigilantes would have to confront defectors to punish them, which incurs risk, and punishment among group members gives rise to grudges and reprisals, which undermine future cooperation. Although groups may be willing to punish individual defectors, people in one-on-one situations may not accept the personal cost of punishment (for example, they are often unwilling to intervene in criminal acts or to testify in trials for fear of retaliation).

Third, the problem remains of what prevents the occurrence of second-order free-riders, who cooperate for the public good but defect from bearing the cost of punishment\(^9\). Fehr and Gächter's results suggest that this is not a problem, as a core of people willingly incur personal costs to administer punishment, motivated by anger (although it is unclear whether they would act on it if they were not anonymous).

Alternative solutions are that punishment may come from an external institution, or it is not costly, or is administered to both may come from an external institution, or a core of people willingly incur personal costs to administer punishment, motivated by anger. Although it is unclear whether they would act on it if they were not anonymous.

A belief in supernatural punishment does not solve the evolutionary puzzle. How could such beliefs evolve if those who did not hold them defected and hence gained an advantage? Laboratory experiments do not support the claim that religion is important for cooperation. If people in the group are expected to defect, then almost everyone else—religious or not—will defect too\(^8\). Moreover, in almost all religions, non-believers have been ostracized and have faced worldly punishment.

We do not agree that anonymity is a problem in the experiment: it rules out other, less costly forms of social punishment that are available in non-anonymous situations, such as workers' hostility towards strike-breakers and people's hostility towards wartime deserters. If non-anonymous punishment were lessened by being more costly, this could be just another example of how remarkable humans are at fine-tuning their behaviour to suit their circumstances.

**Ernst Fehr**, Simon Gächter
*Institute for Empirical Research in Economics, University of Zürich, 8006 Zürich, Switzerland*  
e-mail: efehr@iwr.unizh.ch
†University of St Gallen, FEW-HSG, 9000 St Gallen, Switzerland

---