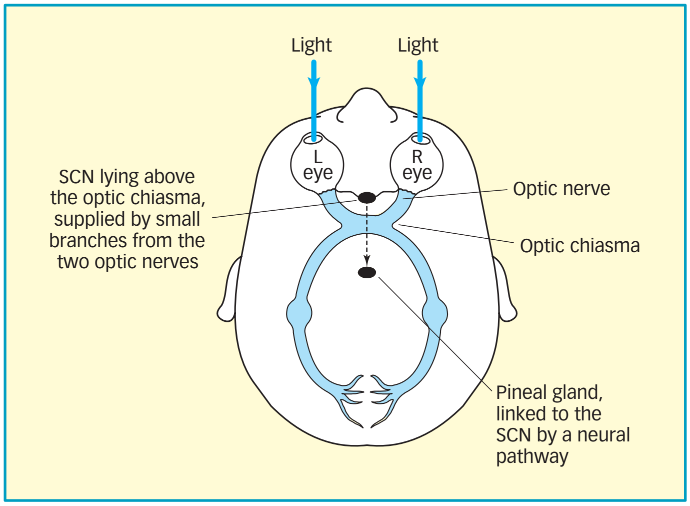


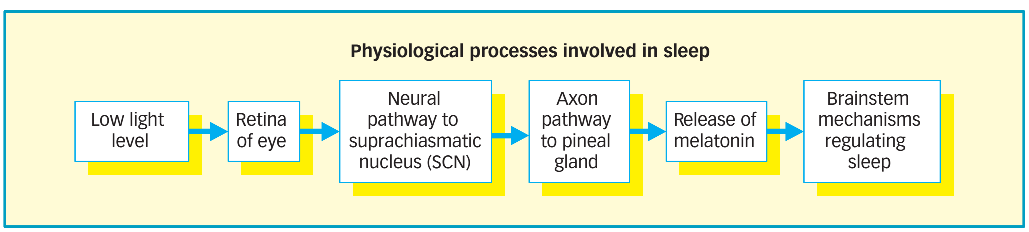
The visual pathway in the brain showing the connection to the suprachiasmatic nucleus (SCN) and onward to the pineal gland.

"time giver") that partially controls biological rhythms. You probably wake up earlier in the summer than in the winter because you respond to the light outside. Czeisler et al. (1999) found that there was an advance in the circadian temperature rhythm when participants were exposed to bright light in the early morning. In contrast, there was a delay in the circadian temperature rhythm when bright light was presented in the late evening.

Much is known of the physiological systems involved in the sleep–wake cycle. The suprachiasmatic nucleus (SCN), which is located within the hypothalamus at the base of the brain, is of special importance (see the figure on the left). The SCN (there are actually two nuclei very close together) is responsive to light and forms the main circadian clock. This was shown convincingly by Ralph, Foster, Davis, and Menaker (1990). They transplanted the SCNs from the fetuses of hamsters belonging to a strain having a 20-hour sleep–wake cycle into adult hamsters belonging to a strain with a 25-hour sleep–wake cycle. These adult hamsters rapidly adopted a 20-hour sleep–wake cycle.

Meijer et al. (1998) took recordings of SCN activity in freely moving animals living in conditions in which lighting remained constant. There was much activity during the part of the animals' circadian rhythm that normally falls in the light and much lower activity during the part of the rhythm typically falling in the night.

Activity in the SCN leads to the release of the hormone **melatonin** from the pineal gland, with more melatonin being released when light levels are low. Melatonin influences the brainstem mechanisms involved in sleep regulation and so helps to control the timing of sleep and waking periods. The involvement of melatonin in the sleep–wake cycle was shown by Schochat, Luboshitzky, and Lavie (1997)—see the Key Study below. There is further evidence. People flying across several time zones often take melatonin, because it makes them feel sleepy 2 hours afterwards (Haimov & Lavie, 1996).



Key Study

Schochat et al. (1997): Melatonin and the sleep–wake cycle

Convincing evidence of the involvement of melatonin in the sleep–wake cycle was reported by Schochat, Luboshitzky, and Lavie (1997). They used the ultra-short sleep–wake paradigm, with six male participants spending 29 hours between 7 a.m. one day and noon the following day in the sleep laboratory. Throughout that time the participants spent 7 minutes in every 20 lying down in bed in a completely darkened room trying to sleep. This method allowed the experimenters to measure sleep propensity (the tendency to sleep) at different times of day. The period of greatest sleep propensity is known as the "sleep gate," and starts in the late evening.

Key Term

Melatonin:
a hormone playing a key role in the onset of sleep.

Surprisingly, the period of lowest sleep propensity (the "wake maintenance zone") occurs in the early evening shortly before the sleep gate.

Shochat et al. (1997) measured the levels of melatonin by taking blood samples up to three times an hour during the 29-hour session. The key finding was as follows: "We demonstrated a close and precise temporal relationship between the circadian rhythms of sleep propensity and melatonin; the noctural [night] onset of melatonin secretion consistently precedes the noctural sleep gate by 100–120 min" (p. R367). This close relationship between increased melatonin levels and increased sleep propensity doesn't prove they are causally related. However, Shochat et al. (1997) discussed other studies strengthening the argument that melatonin is important in determining sleep propensity. For example, individuals suffering from insomnia find it much easier to get to sleep when given melatonin about 2 hours before bedtime (Rosenzweig, Breedlove, & Leiman, 2002).

Discussion points

1. What are some of the good features of the study carried out by Shochat et al.?
2. What are the limitations of their approach?

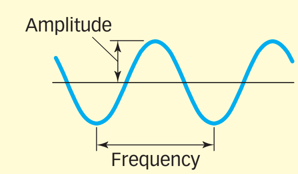
KEY STUDY EVALUATION

Schochat et al.'s results were important in demonstrating that melatonin plays a role in sleep–wake cycles. However, it could be argued that trying to sleep in a laboratory situation is a task that does not have a great deal of ecological validity. The demand characteristics of the experiment and evaluation apprehension may have affected the participants, possibly even at a hormonal level. The sample used by Schochat et al. was also very small, consisting of only six male volunteers, and was not really representative. However, the study, like many others, provides a strong basis for future work.

STAGES OF SLEEP

It is now time to consider what happens during sleep. There are various ways of understanding sleep. However, the electroencephalograph or EEG has proved of particular value. Scalp electrodes are used to obtain a continuous measure of brainwave activity recorded as a trace. Other useful physiological measures include eye-movement data from an electro-oculogram or EOG and muscle movements from an electromyogram or EMG.

There are two main aspects to EEG activity: frequency and amplitude. Frequency is the number of oscillations of EEG activity per second, and amplitude is half the distance between the high and low points of an oscillation. Frequency is used more often than amplitude to describe EEG activity.

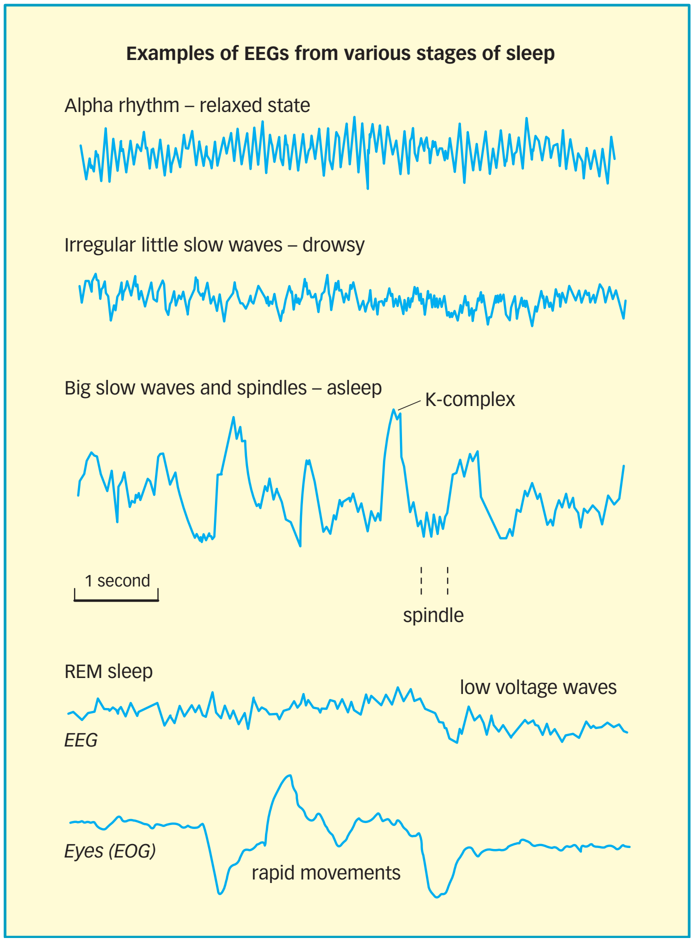


Research using the EEG has revealed five different stages of sleep:

- *Stage 1*: This is a state of drowsiness. It involves high-amplitude alpha waves in the EEG, slow eye rolling, and reductions in heart rate, muscle tension, and temperature.
- *Stage 2*: The EEG waves become slower and larger, but with short bursts of high-frequency sleep spindles. There is little EOG activity.
- *Stage 3*: This is a deeper stage of sleep than either of the first two stages. The EOG and EMG records are similar to Stage 2, but there are many long, slow delta waves with some sleep spindles.
- *Stage 4*: This is a deeper stage of sleep than any of the first three stages. There is a majority of the long, slow delta waves present in smaller amounts in the previous stage, and very little activity in the EOG or EMG.
- *Stage 5*: This is rapid eye movement sleep or **REM sleep**. There are rapid eye movements, a very low level of EMG activity, and small-amplitude fast EEG waves. REM sleep is sometimes called paradoxical sleep, because it is more difficult to awaken someone from REM sleep than from any of the other stages even though the EEG indicates the brain is very active.

Key Term

REM sleep: a stage of sleep involving rapid eye movements and associated with dreaming.



After the sleeper has worked through the first four stages of progressively deeper sleep, he/she reverses the process. Stage 4 is followed by Stage 3, and then by Stage 2. However, Stage 2 is followed by REM sleep (Stage 5). After REM sleep, the sleeper starts another sleep cycle, working his/her way through Stages 2, 3, and 4, followed by Stage 3, Stage 2, and then REM sleep again. A complete sleep cycle lasts about 90 minutes. Most sleepers complete about five sleep cycles during a normal night's sleep. The proportion of the cycle devoted to REM sleep *increases* from one cycle to the next, whereas the time spent in Stage 4 sleep *decreases*.

REM is the most interesting stage of sleep. It is associated with dreaming, with people in REM sleep who are woken up generally reporting that they have just been dreaming. However, dreaming, doesn't only occur in REM sleep. Foulkes and Vogel (1965) found that up to 50% of awakenings from non-REM sleep produced dream reports. However, dreams during REM sleep tend to be vivid and detailed, whereas non-REM dreams contain much less detail and are more "thought-like" (Solms, 2000a). More evidence against a very close association between REM sleep and dreaming was reported by Solms (1997). Damage to the REM-generating parts of the brain stem doesn't stop people from dreaming.

SLEEP DEPRIVATION

We spend about one-third of our lives asleep, making almost 200,000 hours of sleep in the course of an average lifetime! Presumably we wouldn't spend so much of our lives asleep unless sleep served one or more important functions. However, it has proved difficult to identify those functions. One way of trying to work out *why* we sleep is to deprive people of sleep. The problems and impairments experienced by sleep-deprived individuals may be those that sleep is designed to prevent.

People often cope surprisingly well when deprived of sleep for long periods. For example, consider Randy Gardner, a 17-year-old student who remained awake for 264 hours and 12 minutes (11 days) in 1964 (see Horne, 1988). It was difficult to keep him awake from the third night onwards. However, the psychologist William Dement found that playing basketball always did the trick: "We almost had to drag him out to the backyard, but once he was there and got moving, he was much better." Towards the end of the 11-day period, he suffered from disorganized speech, blurred vision, and some paranoia. For example, he thought other people regarded him as stupid because of his impaired functioning.

Randy Gardner was relatively unaffected by sleep deprivation. For example, on the last night of his period of sleep deprivation, he went to an amusement arcade with the psychologist William Dement. They competed several times in a basketball game, and Randy Gardner won every time! At a large press conference at the end of his ordeal, Randy Gardner spoke coherently without slurring his words. Afterwards, he slept for 15 hours. However, over several nights after that he only recovered 25% of the sleep he had missed. In spite of that, he recovered almost 70% of Stage 4 deep sleep and 50% of REM sleep, with very small recovery percentages for the other stages of sleep. These findings suggest that Stage 4 and REM sleep are of special importance.

The effects of sleep deprivation on 10 people were shown on British television in early 2004 in a programme called "Shattered." Ten people were sleep deprived for up to 1 week, with the person staying awake the longest winning £97,000 (approx $188,000). The winner was Clare. She endured 178 hours of sleep deprivation and helped to keep herself awake by tensing her feet until they hurt. One of the contestants thought he was the Prime Minister of Australia, one thought she was in an underground station, and two were certain someone had stolen their clothes.

Hüber-Weidman (1976) reviewed numerous studies on sleep deprivation. After 1 night of sleep deprivation, most people report feeling somewhat uncomfortable. After 2 nights of sleep deprivation, there is a much greater urge to sleep (especially between 3 and 5 a.m.). After 3 nights, performance on complex tasks is much affected, particularly if they are boring. After 4 nights, people become very irritable and confused. They have micro-sleep periods, each lasting about 3 seconds and involving a brief loss of awareness. After 5 nights, some people experience delusions. After 6 nights, there is evidence of "sleep deprivation psychosis" involving a lost sense of personal identity and increased difficulty in coping with other people.

Van Dongen, Maislin, Mullington, and Dinges (2003) studied the effects of restricting sleep to 4 or 6 hours per day for 14 days or to 0 hours for 3 days on a range of cognitive tasks. They found that, "even relatively moderate sleep restriction can seriously impair waking neurobehavioral functions [i.e., on cognitive tasks] in healthy adults" (p. 117). This occurred even though sleepiness ratings suggested that participants had little awareness of the adverse effects on them of sleep deprivation.

Lugaressi et al. (1986) studied a 52-year-old man who hardly slept at all because of damage to parts of his brain (e.g., the thalamus) involved in sleep regulation. Not surprisingly, he became absolutely exhausted and couldn't function effectively. Some individuals (including the man studied by Lugaressi et al., 1986) inherit a defect in the gene for the prion protein, leading to degeneration of the thalamus and to **fatal familial insomnia**. The typical age of onset is about 35 or 40 years. However, it ranged between 20 and 60 in an Austrian family with fatal familial insomnia in five consecutive generations (Almer et al., 1999). Individuals with fatal familial insomnia typically die within 2 years of the onset of the insomnia (Almer et al., 1999; Medori et al., 1992).

In sum, there is remarkably little evidence that sleep deprivation for up to 1 week has major long-term consequences. There are emotional changes (e.g., irritability; tension) and intellectual changes (e.g., some confusion; performance impairment), but these changes are rapidly reversed by 1 long night's sleep. Even very prolonged sleep deprivation as in fatal familial insomnia can continue for several months or even a year or two before it leads to death.

Overview of sleep-deprivation studies

Nights without sleep	*Effects*
1	People do not feel comfortable, but can tolerate 1 night's sleep loss
2	People feel a much greater urge to sleep, especially when the body-temperature rhythm is lowest at 3–5 a.m.
3	Cognitive tasks are much more difficult, especially giving attention to boring ones. This is worst in the very early hours.
4	Micro-sleep periods start to occur, lasting about 3 seconds, during which the person stares blankly into space and temporarily loses awareness. They become irritable and confused.
5	As well as what is described above, the person may start to experience delusions, though cognitive ability (for example problem solving) is all right.
6	The person starts to lose their sense of identity, to be depersonalized. This is known as sleep-deprivation psychosis.

Source: Bentley (2000), p. 47.

THEORIES OF SLEEP

Evidence relevant to the issue of the functions served by sleep can be obtained by considering sleep amounts across different species. There are surprisingly large variations. For example, bats and opossums sleep for 18–20 hours per day, whereas elephants and giraffes sleep only 3–4 hours a day.

Siegel (2005) reviewed the evidence about sleep in numerous species of mammal. He concluded that the large variations in sleeping time across species indicate that the functions of sleep differ in complex ways from one species to another. Most theories of sleep can be assigned to two broad classes or categories: (1) recovery or restoration theories; and (2) adaptive or evolutionary theories. Pinel (1997, p. 301) gave a brief indication of the essence of each type of theory: "Recuperation [recovery] theories view sleep as a nightly repairman [sic] who fixes damage caused by wakefulness, while circadian [adaptive] theories regard sleep as a strict parent who demands inactivity because it keeps us out of trouble."

We will discuss both types of theories shortly. Before doing so, however, it is worth emphasizing that the two theories are complementary rather than in direct conflict.

Key Term

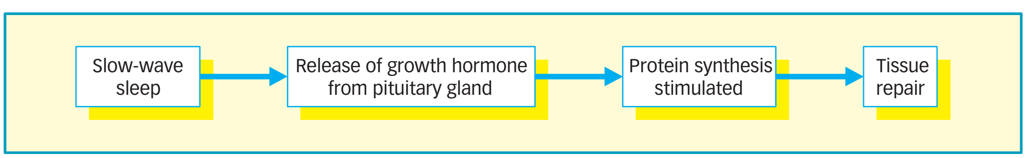
Fatal familial insomnia: an inherited disorder in which the ability to sleep disappears in middle age and is followed by death several months later.

The amount of sleep varies quite drastically across different species. Bats and possums sleep for 18–20 hours per day, whereas elephants and giraffes sleep for just 3–4.

Recovery/restoration theories focus mainly on the issue of *why* we need to sleep. In contrast, adaptive-evolutionary theories concentrate on the issues of *when* we sleep and *how long* we sleep each day. Combining the insights of the two theories provides promising answers to the main questions concerning the functions of sleep in humans and other species.

RECOVERY OR RESTORATION THEORIES

It is reasonable to assume that sleep serves the functions of saving energy and permitting the restoration of tissue. These notions are central to recovery or restoration theories (e.g., Horne, 1988, 2001; Oswald, 1980). According to Oswald's recovery theory, slow-wave sleep (Stages 1–4) is useful for recovery processes in the body. For example, there is a substantial release of growth hormone from the pituitary gland during slow-wave sleep (Takahashi, 1979). Horne (2001) argued that sleep is important for the recovery of brain function, especially that of the prefrontal cortex. The prefrontal cortex is involved in decision making and effective responding to unexpected events, both of which are impaired by sleep deprivation (Harrison & Horne, 2000). For example, serious disasters or near-disasters at four nuclear power stations (Chernobyl, Three Mile Island, Rancho Seco in Sacramento, and Davis-Beese in Ohio) all occurred very early in the morning.



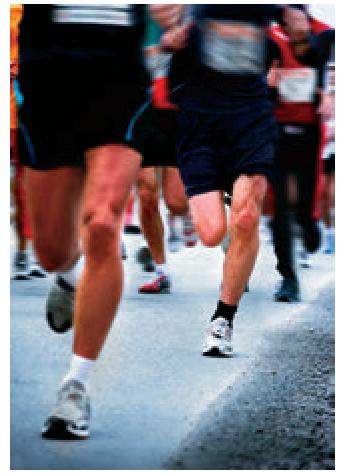
Findings

Allison and Cicchetti (1976) considered the amount of time spent in slow-wave sleep and in REM sleep across 39 species of mammals. Body weight was the best predictor of short-wave sleep, with smaller mammals having more such sleep. Metabolic rate, which is highly correlated (negatively) with body weight, was also very predictive of short-wave sleep. Different factors predicted the amount of REM sleep. Vulnerability to danger (e.g., danger of being preyed on) was the best predictor of REM sleep—those most vulnerable had the least REM sleep. That makes sense given that it is most difficult to waken an animal when in the REM stage.

So far as recovery theories are concerned, Allison and Cicchetti's (1976) key finding was the association between metabolic rate and the duration of slow-wave sleep. This association may occur because small mammals are in particular need of the energy conservation function of sleep because of their high metabolic rate. Another interpretation is that large mammals (especially herbivores who live on grass or other plants) need to spend most of their time searching for food and so can't afford the luxury of long periods asleep.

Oswald (1980) claimed that important recovery processes occur in the brain during REM sleep. In support, newborn infants (who experience enormous brain growth) spend a very high percentage of their time asleep devoted to REM sleep (Green, 1994). More generally, growth processes of all kinds are much more important in newborn infants and young children. Their greater need for the release of growth hormone during sleep may help to explain why neonates sleep for about 16 hours a day, reducing to 12 hours a day by the age of 2.

If an important function of sleep is recovery, then individuals who are extremely active during the day (or who are sleep deprived) would presumably need more sleep than other people. This might be especially the case for the most important stages of sleep (Stage 4 slow-wave sleep and REM sleep). There is support for these predictions. Shapiro et al. (1981) studied runners who had taken part in an ultra-marathon covering 57 miles. These runners slept about 90 minutes longer than usual on the 2 nights afterwards. In addition, they showed an especially large increase in the amount of time devoted to Stage 4 sleep. Earlier we discussed the case of Randy Gardner who stayed awake for 11 days. He slept for 15 hours after his extremely long period of sleep deprivation, and an unusually high proportion of his sleep time was devoted to REM and Stage 4 sleep.


Although studies show that people need extra sleep following extreme exertion, there is no evidence that people who take little or no exercise reduce their sleeping time.

A major difference between recovery and adaptive theories is that only the former claim that sleep is essential. The finding (discussed earlier) that individuals suffering from fatal familial insomnia typically die within 2 years of the start of the insomnia (e.g., Almer et al., 1999) provides some support for recovery theories.

What about Horne's (2001) assumption that sleep permits recovery of brain function, especially that of the prefrontal cortex? Maquet (2000) found that there was a considerable amount of brain shutdown during slow-wave sleep (especially Stage 4), and this shutdown was very pronounced in the prefrontal cortex. Muzur, Pace-Schott, and Hobson (2002) reviewed evidence indicating that there is deactivation of the dorsolateral prefrontal cortex in sleep, which impairs its functions such as self-consciousness and analytical thought. Brain-imaging studies indicate that sleep deprivation has especially great effects on the prefrontal cortex (Drummond et al., 2000). Nilsson et al. (2005) found that only 1 night's sleep deprivation produced significant impairment on a task requiring executive functions dependent on activity in the prefrontal cortex.

Evaluation

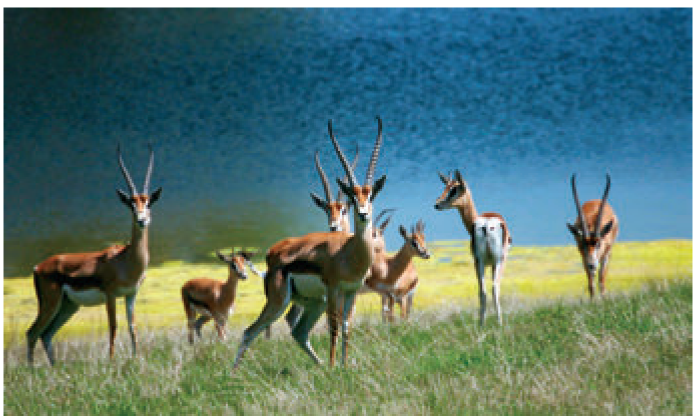
- \+ Recovery theories provide plausible reasons why sleep is important and essential.
- \+ The fact that sleep is found in virtually all species (except perhaps some whales and dolphins—see Siegel, 2005) is consistent with the notion that it is essential.
- \+ The fact that total sleep deprivation in fatal familial insomnia leads to death within 2 years supports the view that sleep is essential.
- \+ The finding that sleep deprivation and excessive activity both lead to unusually long periods of sleep and enhanced proportions of Stage 4 and REM sleep supports recovery theories.
- \+ There is increasing evidence that sleep permits recovery of the executive functions of the prefrontal cortex, whereas sleep deprivation has adverse effects on those functions and on the prefrontal cortex.
- − It has proved difficult to specify in detail the physiological processes restored by sleep.
- − Evidence about relative amounts of sleep time in different species of mammals is open to various interpretations and doesn't strongly support recovery theories.

ADAPTIVE OR EVOLUTIONARY THEORIES

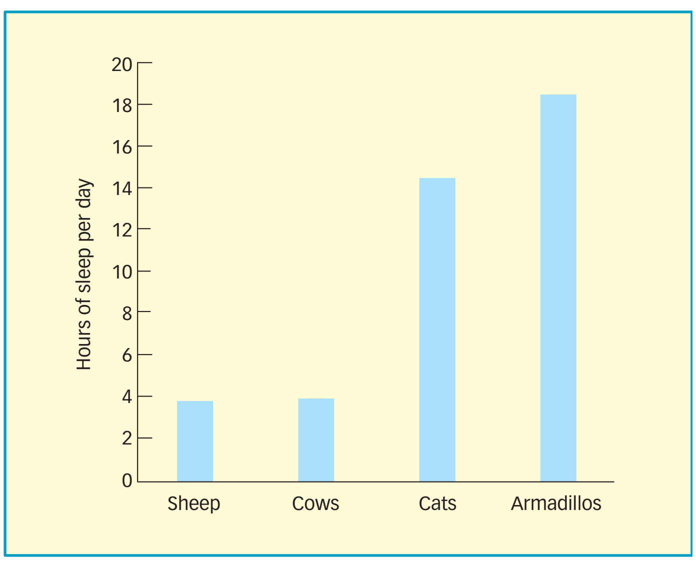
According to various theorists (e.g., Kavanau, 2005; Meddis, 1979), sleep is adaptive behavior favored by evolution. For example, the sleep behavior shown by many species may depend on the need to adapt to environmental threats and dangers. Sleep can serve the function of keeping animals fairly immobile and safe from predators during periods of time when they can't engage in feeding and other kinds of behavior. In the case of those species dependent on vision, it is adaptive to sleep during the hours of darkness. In addition, sleep fulfills the useful function of conserving energy.

It seems to follow that species in danger from predators should sleep more of the time than those species that are predators. In fact, however, predators tend to sleep more than those preyed on (Allison & Cicchetti, 1976). This might seem inconsistent with adaptive theories of sleep. However, species in danger from predators might well benefit from remaining vigilant most of the time and sleeping relatively little. This seems like an example of having your cake and eating it, in that any pattern of findings can be explained by the adaptive or evolutionary approach! However, the basic assumption that the pattern of sleep shown by each species has been influenced by evolutionary pressures seems reasonable although difficult to prove.

Kavanau (2005) has recently put forward an interesting evolutionary approach to understanding sleep. He pointed out that visual perception in many species (including humans) requires very large amounts of brain processing. Indeed, a substantial proportion of the human brain is devoted to visual processing. According to Kavanau, sleep frees the brain from effortful visual processing and thus allows memory processing to proceed more efficiently.



Herbivores, such as these springbok, need to graze most of the time and be on their guard against predators, so sleep relatively little.



Findings

Support for the notion that the pattern of sleep is often dictated by the environmental threats faced by animals was reported by Pilleri (1979). Dolphins living in the river Indus are in constant danger from debris floating down the river. As a result, these dolphins sleep for only a few seconds at a time to protect themselves from the debris. More generally, as we have seen, species vulnerable to attack by other species sleep less than those under little or no threat (Allison & Cicchetti, 1976).

Sleep patterns within most species are adaptive. Several species of mammal that are unlikely to be attacked and that eat food rich in nutrition sleep most of the time. For example, cats sleep 14.5 hours a day, and armadillos sleep 18.5 hours a day. In contrast, herbivores (plant eaters) need to graze most of the time and be on their guard against predators, and so sleep relatively little. For example, sheep sleep on average 3.8 hours per day, and cows 3.9 hours a day.

What evidence indicates that sleep is useful in conserving energy as predicted by adaptive theories? The body temperature of most mammals is slightly lower during sleep, suggesting sleep is helpful for energy conservation. Stronger evidence was reported by Berger and Phillips (1995). Animals responded to food shortages by increasing the amount of time they spent asleep or by decreasing their body temperature more than usual in the sleeping conservation. However, sleep in humans is of little value in energy conservation. As Horne (2001, p. 302) pointed out, "The energy saved by being asleep throughout the night rather than sitting relaxed but awake is trivial—the energy equivalent to a slice of bread."

Kavanau's (2005) assumption that sleep is useful because it frees us from the high processing demands of visual perception fits many findings. First, sleep is found mainly in species that engage in detailed visual processing. Species that are genetically blind (e.g., cave fishes) don't sleep (see Kavanau, 2005). Evidence supporting this theory comes from the study of box jellyfish (*Chironex fleckeri*), which are found in tropical Australia and can kill humans within minutes. It had been thought that jellyfish didn't sleep but recent research discussed by Kavanau (2006) indicates that box jellyfish often sleep 15 hours a day. Box jellyfish have 24 eyes of four different types, and it is likely that the typical demands of visual processing on their simple nervous system explain their need for so much sleep. However, the situation is very different in box jellyfish that live in captivity and are hand fed. These jellyfish do not need to engage in complex visual processing (e.g., to locate prey and avoid predators) nor do they need to remember where food is to be found. As a result of the limited demands on their visual and memory systems, captive box jellyfish hardly sleep at all.

Second, most species that sleep have to block their vision in order to sleep. Third, there are many species of birds and marine mammals in which the brain instantly falls asleep when they close their eyelids and instantly awakens when they open their eyelids.

Sleep is generally regarded as less essential within adaptive theories than within recovery theories. Modest support for adaptive theories comes from individuals leading healthy lives in spite of regularly sleeping for very short periods of time each day (e.g., Meddis, Pearson, & Langford, 1973). For example, Miss M was a cheerful 70-year-old nurse who typically slept for only 1 hour per day. She generally sat on her bed reading or writing until about 2 in the morning, after which she would sleep for about 1 hour. When she was studied under laboratory conditions, she slept an average of 67 minutes per night.

Evaluation

- + Adaptive theories provide reasonably plausible explanations of why species vary in their sleeping patterns.
- + Adaptive theories have identified factors (e.g., vulnerability to attack; feeding patterns; importance of vision) helping to determine differences in amount and timing of sleep across species.
- + The notion that sleep serves to conserve energy is supported by the evidence from numerous species.
- + There is support for Kavanau's (2005, 2006) theory that an important evolutionary function of sleep is to eliminate visual processing and permit long-term storage of information.
- − Most adaptive theories provide no obvious explanation for the existence of fatal familial insomnia, in which prolonged sleep deprivation causes death.
- − Some of the claimed benefits of sleep (e.g., energy conservation; preventing effortful visual processing) could be obtained by simply resting with the eyes closed (Gamundi et al., 2005).

DREAMING

What is dreaming? According to Solms (2000a, p. 849), it is "the subjective experience of a complex hallucinatory episode during sleep." There are several important differences between dreaming and waking consciousness. As was discussed earlier, many of these differences seem to reflect reduced activation in the prefrontal cortex during dreaming. First, we typically feel we have little or no control over our dreams. In contrast, we nearly always have a sense (perhaps mistaken!) of conscious control in our waking lives. However, people occasionally have lucid dreams, in which they know they are dreaming and can sometimes control the dream content. For example, LaBerge, Greenleaf, and Kedzierski (1983) studied a woman who could create lucid sex dreams producing orgasms.

Sleepwalking

Dreams don't always occur in REM sleep. REM dreaming is accompanied by paralysis, probably to protect the sleeper from acting out their dreams and injuring themselves. People also dream in non-REM (NREM) sleep, but less often, and they are not in a paralyzed state. It is possible to act out NREM dreams, which can lead to sleepwalking.

Sleepwalking is more common than one might guess. Thirty percent of all children between the ages of 5 and 12 have walked in their sleep at least once, and persistent sleepwalking occurs in 1–6% of youngsters. Boys walk in their sleep more often than girls, and the tendency to wander during deep sleep is sometimes inherited from one of the parents.

The typical sleepwalking episode begins about 2 hours after the person goes to sleep, when they suddenly "wake" and abruptly sit up in bed. Although their eyes are wide open, they appear glassy and staring. When asked, sleepwalkers respond with mumbled and slurred single-word speech. The person may perform common acts such as dressing and undressing, opening and closing doors, or turning lights on and off. Sleepwalkers seem to see where they are going since they avoid most objects in their way, but they are unaware of their surroundings. Unfortunately, this means that they cannot tell the difference between their bedroom door and the front door, or the toilet and the wastebasket. The sleepwalker is usually impossible to awaken and does not remember the episode in the morning. The episode typically lasts 5 to 15 minutes and may occur more than once in the same night.

Although sleepwalkers avoid bumping into walls and tripping over furniture, they lack judgment. A sleepwalking child might do something like going to the garage and getting in the car, ready to go to school at 4 o'clock in the morning. Sometimes their lack of judgment can be dangerous. One sleepwalking child climbed a tree and another was found by the police walking down the street in the middle of the night. Therefore, sleepwalkers are in danger of hurting themselves and must be protected from self-injury.

Most children outgrow sleepwalking by the time they are teenagers, but for a small number of individuals the pattern continues into adulthood.

Christian Murphy escaped with cuts and bruises when he fell from his first-floor bedroom window while sleepwalking. His mother's Mercedes that was parked below broke his fall. Once he had landed he got up, still sleepwalking, and set off down the road.

Second, dreams often contain elements that would seem illogical or nonsensical in our waking consciousness. For example, dreams sometimes include impossible events or actions (e.g., someone floating above the ground), and they can also include various hallucinations and delusions.

Third, we are often totally absorbed by our dream imagery, reflecting what Empson (1989) described as "the single-mindedness of dreams." In contrast, when we are awake, we can usually stand back from our conscious thoughts and avoid being dominated by them.

Most dreams take place during REM (rapid eye movement) sleep. However, the common view that dreaming *only* occurs during REM sleep and that REM sleep is always associated with dreaming is profoundly mistaken. Nielsen (1999) reviewed studies in this area. On average, individuals woken up during REM sleep recalled dream-like material on only 82% of occasions compared to 42.5% during non-REM sleep. What was recalled from REM sleep was typically more vivid, more emotionally loaded, and of less relevance to waking life than recall from non-REM sleep.

According to Dietrich's (2003) transient hypofrontality hypothesis (discussed earlier), a key characteristic of dreaming is that it is associated with low levels of prefrontal activation. Muzur, Pace-Schott, and Hobson (2002, p. 475) reviewed the evidence on dreaming and sleep, and came to the following conclusion: "As a consequence of deactivation of the dorsolateral prefrontal cortex (DLPFC) during sleep, executive functions such as self-consciousness and analytical thought are severely impaired in NREM sleep and are weak in REM sleep."

We spend on average over 2 hours a night dreaming. It doesn't seem that we dream that much, because we forget more than 95% of our dreams. What are these forgotten dreams about? Researchers have answered this question by using sleep laboratories, in which sleepers are woken up mainly during REM sleep. The dreams typically forgotten tend to be more ordinary and less bizarre than those we remember in everyday life (Empson, 1989). This means that the dreams we remember spontaneously are not typical of our dreams in general. It would thus *not* be appropriate to base a theory of dreaming purely on the 5% of dreams we normally remember.


This patient's brain activity during the various cycles of sleep is being measured as part of a sleep research program. The electrical activity of the brain is measured by placing electrodes on the patient's scalp to produce an electroencephalogram (or EEG).

There is another potential problem. As Coenen (2000, p. 923) pointed out, "A dream is what someone describes upon awakening and researchers infer a one-to-one relationship between the dream and the way it is reported. It is therefore impossible to exclude such confounding factors as poor memory, overestimation, suppression or the effects of psycho-emotional factors on recall."

FREUD'S WISH FULFILLMENT THEORY

According to Sigmund Freud (1900, p. 377), dreams are like "a firework that has been hours in the preparation, and then blazes up in a moment." However, his central claim was that "wish fulfillment is the meaning of each and every dream" (Freud, 1900, p. 106). Why is wish fulfillment the main goal of dreams? According to Freud, our minds when asleep aren't influenced by the external environment or by the constraints it imposes on our behavior. Instead, we are influenced by internal factors (e.g., basic sexual and other motivational forces). We imagine acting in accordance with these motivational forces when dreaming, and this preserves sleep.

Dreamers' wish fulfillments are often regarded as unacceptable by the dreamer, leading Freud to describe dreams as "the insanity of the night." How do dreamers deal with the unacceptable nature of their dreams? According to Freud, the actual dream and its meaning (the **latent content**) are distorted into a more acceptable form (the **manifest content**) by the time dreamers are consciously aware of their dream. Dream-work is involved in transforming and "cleaning up" the original unconscious wishes into the manifest content of the reported dream. Here are some of the mechanisms used in dream-work:

1. *Displacement*: An element in the dream is substituted by something else (e.g., having sex is represented by riding a horse).
2. *Regression*: Thoughts are transformed into perceptions (e.g., the sizes of individuals in a dream reflect their significance to the dreamer).
3. *Condensation*: Several dream elements are combined in a single image (e.g., failure and sadness are represented as a descending escalator).

How can we identify the original latent content of a dream on the basis of its manifest content? This involves some of the techniques of psychoanalysis. For example, the dreamer provides associations to the various aspects of the manifest content, and these associations form the basis for working out the underlying themes. This might reveal that licking a lollipop is a symbol for oral sex or a cigar is a symbol for a penis. However, as Freud himself admitted, "Sometimes a cigar is only a cigar."

Findings

Freud (1900) provided some examples apparently showing that dreams involve wish fulfillment. For example, he reported that his 19-month-old daughter Anna called out in

Key Terms

Latent content: in Freud's theory, the underlying meaning of a dream that is difficult to recollect consciously; see **manifest content**.

Manifest content: in Freud's theory, the remembered, "cleaned up" meaning of a dream; see **latent content**.

her sleep, "Anna Freud, strawberry, wild strawberry, scrambled eggs, mash," after not having eaten anything all day (Freud, 1900, p. 104). In similar fashion, Wood (1962) found that people who had been kept socially isolated throughout the day were more likely than controls to dream about being with other people.

If dreams represent wish fulfillments, most of them should be associated with positive emotional states. In fact, that is not the case. Hall and van de Castle (1966) found in a study of 1000 dreams that seven times as many involved misfortune (e.g., mishaps; danger) as good fortune. Zadra (1996) examined recurrent dreams in children and adults. About 85% of these dreams contained negative or unpleasant emotions, and only 10% contained exclusively pleasant emotions. Even Freud (1955, p. 32) admitted that, "It is impossible to classify as wish fulfillments the dreams . . . which occur in traumatic neurosis [suffered by combatants in the First World War], or the dreams during psychoanalysis which bring to memory the traumas of childhood."

Politics and dream content

The Association for the Study of Dreams (2001) found that political views could influence dream content. People with right-wing views report having more violent and scary dreams than people with left-wing views. If this is true, it could support the Freudian view that dreams have a hidden content or message.

Freud based his theory on dreams spontaneously remembered by dreamers. However, such dreams account for only about 5% of all dreams. In fact, most dreams are concerned with the trivial matters of everyday life and lack the dramatic emotional quality that Freud attributed to them.

Freud's theory is also wrong in other respects. First, it is untrue that dreams are infrequent and very short-lasting. In fact, they are much more frequent and long-lasting than Freud assumed (Empson, 1989). Second, Freud argued that dreams preserve sleep. However, Solms and Turnbull (2002) found that only 49% of patients who had lost the ability to dream reported disrupted sleep. Third, Freud claimed that reported dreams (the manifest content) involve substantial distortions from the underlying dream (the latent content). However, various studies have indicated that the differences are much smaller than would be predicted on Freud's theory (see Domhoff, 2001, for a review).

Solms (2000b) has carried out research more supportive of Freud. He has found that dreaming is eliminated in patients with damage to the "seeking system" connecting the midbrain to the limbic system and the frontal lobes. This system "instigates goal-seeking behaviors and an organism's appetitive interactions with the world" (Panksepp, 1985, p. 273). Solms claimed that this system is associated with the sexual instinct emphasized by Freud in his dream theory.

Evaluation

- + Freud put forward the first systematic theory of dream function. He explained why dreams often seem rather incoherent (transformation of the latent content into the manifest content).
- + As Freud argued, dreams tell us something about the thoughts and feelings of the dreamer, but less than he imagined.
- + Brain areas of crucial importance in dreaming are of relevance in sexual and other motivation.
- − Freud emphasized that dreams involve repressed unacceptable desires. However, that seems much less relevant in today's permissive society than in nineteenth century Vienna. In addition, most dreams not recalled spontaneously are concerned with rather ordinary and trivial events.
- − It is difficult to regard most dreams (e.g., nightmares) as wish fulfilling even in a distorted way.
- − The assumptions that dreams are infrequent and brief, that they preserve sleep, and that reported dreams are very distorted from the original dreams are all incorrect.

ACTIVATION–SYNTHESIS THEORY

Hobson and McCarley (1977) were impressed by the fact that parts of the brain are as active during rapid eye movement (REM) sleep as during normal waking. This led them to put forward the activation–synthesis theory of dreaming. According to this theory, the state of activation during REM sleep depends mainly on the pontine brain stem, which is also responsible for triggering dreaming. Activity in the pontine brain stem produces high levels of activation in several parts of the brain, including those involved in perception, action, and emotional reactions. Of key importance, this activation is essentially *random*.

The forebrain then makes "the best of a bad job in producing even partially coherent dream imagery from the relatively noisy signals sent up to it from the brain stem" (Hobson & McCarley, 1977, p. 1347). How does the brain make coherent sense of random activity? According to Hobson (1988), "The brain is so inexorably bent upon the quest for meaning that it attributes and even creates meaning when there is little or none in the data it is asked to process."

In sum, the activation–synthesis theory makes three main assumptions:

1. A high level of activation in pontine brainstem mechanisms is needed for dreaming to occur.
2. Activation in pontine brainstem mechanisms produces REM sleep as well as dreaming. It was originally assumed that all dreams occur during REM sleep but it is now accepted that dreaming can occur in non-REM sleep as well (Hobson et al., 2000).
3. The forebrain tries to impose meaning on the more-or-less random activation from the brain stem to produce partially coherent dreams.

Findings

Some of the evidence supports activation–synthesis theory. For example, Hobson, Pace-Schott, and Stickgold (2000) reviewed studies showing activation of the pontine brain stem and parts of the forebrain during REM sleep. It follows from the theory that brainstem lesions should eliminate REM sleep, and this has been found in studies on patients with lesions in the brain stem (Solms, 2000a).

According to the theory, lesions of the pontine brain stem should also eliminate dreaming. However, this is typically *not* the case. Solms (2000a) concluded that there was clear evidence of cessation of dreaming in only one out of 26 patients with severe damage to the pontine brain stem.

According to the theory, brain-damaged patients who dream rarely or never shouldn't have REM sleep. Solms (2000a) showed convincingly that this is not the case. He reviewed 111 cases of nondreamers, all but one of whom had preserved REM sleep. Thus, the presence of REM sleep doesn't guarantee that dreaming will occur.

According to the theory, most dreams should be rather incoherent and even bizarre. *Some* dreams are certainly bizarre, but that is not true of the great majority. For example, Hall (1966) examined 815 reports of dreams occurring at home or in the laboratory. Only about 10% contained at least one "unusual element." However, it is true that people when dreaming are much less likely to realize that events are outlandish or absurd than when they are awake (Kahn & Hobson, 2005).

Why did Hobson and McCarley (1977) claim that dreams are bizarre and incoherent? According to Vogel (2000, p. 1014), this view "is based mostly upon reported dreams that are spontaneously recalled in the morning. These dreams are likely the most dramatic, bizarre dreams and are not representative of dream life in general. The collection of large dream samples from throughout the night from ordinary people . . . has shown that dreams are mundane, organized, everydayish stories."

Evaluation

+ The theory is based on detailed information about brain activity during sleep and dreaming.
+ Dreams are often triggered by activation of the pontine brain stem, but such stimulation is not essential (Solms, 2000a).

+ Random activity in the brain and inefficiently functioning attentional processes may make some dreams difficult to understand.
− The original idea that dreaming occurs only during REM sleep has had to be abandoned. As Solms (2000a, p. 843) pointed out, “REM is controlled by cholinergic brainstem mechanisms whereas dreaming seems to be controlled by dopaminergic forebrain mechanisms.”
− The theory exaggerates the importance of the pontine brain stem (see Solms, 2000a) and minimizes the reduction in prefrontal activity found during dreaming (Muzur, Pace-Schott, & Hobson, 2002).
− Most dreams are reasonably coherent rather than bizarre as predicted by the theory.

Chapter Summary

Consciousness

- It has been argued that humans developed consciousness to understand other people and to control our actions.
- According to Wegner, we have only the illusion of conscious or free will. We use the evidence available to us to *infer* that our thoughts caused our actions. However, Wegner only showed that we are occasionally mistaken when deciding what caused one of our actions.
- It has sometimes been claimed that split-brain patients have two consciousnesses. It is more likely that they have a single conscious system (the interpreter) based in the left hemisphere.
- According to global workspace theories, there is a close connection between focal attention and consciousness. In addition, consciousness is associated with the combining and integrating of information from nonconscious processes throughout the brain.
- Many different brain areas can be associated with conscious awareness. However, two areas that are typically involved are the prefrontal cortex and the anterior cingulate.

Sleep

- In the free-running paradigm (in which individuals can control their own lighting conditions), individuals often exhibit a 25-hour sleep–wake cycle. However, there is evidence for a 24-hour cycle when a forced desychrony paradigm is used.
- Activity in the suprachiasmatic nucleus leads to the release of the hormone melatonin, which is followed 2 hours later by sleepiness.
- There are five major stages of sleep defined physiologically. Rapid eye movement (REM) sleep is the stage most associated with dreaming.
- Individuals generally cope surprisingly well with prolonged sleep deprivation. However, lengthy sleep deprivation often leads to impaired performance, irritability, and delusions.
- Individuals with fatal familial insomnia hardly sleep at all and typically die within 2 years of the onset of the insomnia.
- Recovery or restoration theories claim that sleep saves energy and restores tissue. In contrast, adaptive or evolutionary theories argue that sleep serves the function of keeping humans and other species out of trouble or that it reduces the demands of constant visual processing. The two types of theories can be regarded as complementary rather than in conflict with each other.

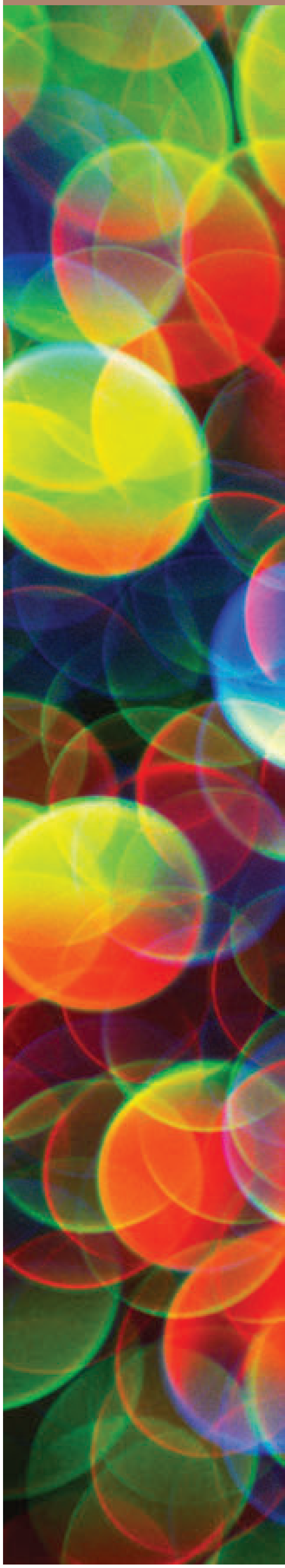
Dreaming

- Most dreams occur during REM sleep, but many dreams occur during non-REM sleep. About 95% of dreams are forgotten.

- According to Freud, dreams involve wish fulfillment. They are short-lasting and infrequent, they preserve sleep, and reported dreams are distorted versions of the original dream.
- Freud explained why dreams can be incoherent. As he predicted, brain areas associated with sexual motivation tend to be activated during dreaming.
- Most dreams involve unpleasant emotions, and it is implausible to claim that such dreams involve wish fulfillment. Most of the other assumptions made by Freud are incorrect.
- According to activation–synthesis theory, dreaming involves the forebrain trying to make sense of essentially random activation coming from the pontine brain stem and responsible for REM sleep.
- Dreams are often (but not always) triggered by activation of the pontine brain stem.
- The role of the pontine brain stem is exaggerated in activation–synthesis theory, and most dreams are more coherent than predicted by that theory. In addition, the importance of the reduction in prefrontal activation found during dreaming is minimized.

Further Reading

- Blackmore, S. (2003). *Consciousness: An introduction*. London: Hodder & Stoughton. This interesting book is written in a lively and entertaining way and provides the ideal introduction to the topic of consciousness.
- Blackmore, S. (2005). *Conversations in consciousness*. Oxford, UK: Oxford University Press. This is an interesting book based on the author's interviews with leading experts.
- Breedlove, S.M., Rosenweig, M.R., & Watson, N.V. (2007). *Biological psychology: An introduction to behavioral, cognitive, and clinical neuroscience* (5th ed.). Sunderland, MA: Sinauer Associates. The biological approach to sleep is covered in detail in this textbook.
- Domhoff, G.W. (2001). Why did empirical dream researchers reject Freud? A critique of historical claims by Mark Solms. *Dreaming*, *14*, 3–17. Domhoff pinpoints with clarity the major limitations with Freud's theory of dreaming.
- Hobson, J.A., Pace-Schott, E.F., & Stickgold, R. (2000). Dreaming and the brain: Toward a cognitive neuroscience of conscious states. *Behavioral and Brain Sciences*, *23*, 793–842. This long article provides a revised version of one of the most influential theories of dreaming.
- Roser, M., & Gazzaniga, M.S. (2004). Automatic brains—interpretive minds. *Current Directions in Psychological Science*, *13*, 56–59. This article summarizes contemporary views on consciousness, including the relevance of split-brain research.
- Siegel, J.M. (2005). Clues to the functions of mammalian sleep. *Nature*, *437*, 1264–1271. This article provides an up-to-date review of evidence relating to the possible functions of sleep.
- Solms, M. (2000a). Dreaming and REM sleep are controlled by different brain mechanisms. *Behavioral and Brain Sciences*, *23*, 843–850. Some of the main brain areas associated with dreams are identified clearly in this article by an expert in the field.
- Wegner, D.M. (2002). *The illusion of conscious will*. Cambridge, MA: MIT Press. This controversial book is based on the assumption that we are mistaken when we believe our actions are determined by our conscious intentions.



PART

II

INTRODUCTION TO Cognitive Psychology

FOUR MAJOR APPROACHES

One of the most dramatic changes within cognitive psychology in recent decades has been the huge increase in the number of weapons available to cognitive psychologists. Forty years ago, most cognitive psychologists carried out laboratory studies on healthy individuals. Nowadays, in contrast, many cognitive psychologists study brain-damaged individuals, others construct elaborate computer-based models of human cognition, and still others use numerous brain-imaging techniques.

Four major approaches to human cognition have now been developed:

- *Experimental cognitive psychology*: This is the traditional approach and involves carrying out experiments on healthy individuals, typically under laboratory conditions.
- *Cognitive neuropsychology*: This approach involves studying patterns of cognitive impairment shown by brain-damaged patients to provide valuable information about normal human cognition.
- *Computational cognitive science*: This approach involves developing computational models to further our understanding of human cognition.
- *Cognitive neuroscience*: This approach (which has become of major importance within the last 15 years) involves using numerous brain-imaging techniques to study aspects of brain functioning and structure relevant to human cognition. Note that the term "cognitive neuroscience" is often used in a broader sense to indicate an approach to understanding human cognition based on considering evidence about brain functioning as well as about behavior, and about how brain functioning influences behavior. What is common to both definitions is the importance attached to the use of brain-imaging techniques.

There is no need for researchers to select only one of these approaches at the expense of the other three. Indeed, cognitive psychologists increasingly use two (or even three) of these approaches in their research.

EXPERIMENTAL COGNITIVE PSYCHOLOGY

Experiments carried out on healthy individuals under laboratory conditions tend to be tightly controlled and "scientific." Experimental cognitive psychology was for many years the engine room of progress in cognitive psychology. Indeed, all three of the newer approaches to cognitive psychology have benefited from it. For example, consider the case of cognitive neuropsychology. It was only when cognitive psychologists had developed reasonable accounts of normal human cognition that the performance of brain-damaged patients began to be understood properly. Before that, it was hard to decide which patterns of cognitive impairment were theoretically important. Cognitive neuropsychologists often carry out studies on individual patients, and use the data from such patients to test theoretical predictions coming from experimental cognitive psychology. Such studies would be of little interest in the absence of an appropriate pre-existing theory.

Problems about the artificiality of laboratory research have often been expressed by claiming that such research lacks external validity or ecological validity (see Chapter 2). Ecological validity has two aspects: (1) representativeness; and (2) generalizability. Representativeness refers to the naturalness of the experimental situation, stimuli, and task. Generalizability refers to the extent to which the findings of a study are applicable to the real world. Generalizability is more important than representativeness. As a result, we need to reassure ourselves that experimental studies possess generalizability (many don't!).

COGNITIVE NEUROPSYCHOLOGY

Cognitive neuropsychology is concerned with the cognitive performance of brain-damaged patients, using the information gained to understand normal cognition. We consider two of the main assumptions of cognitive neuropsychology (see Coltheart, 2001). First, the cognitive system is based on modularity, meaning that it consists of numerous independent processors or modules. For example, the modules or processors involved in understanding speech differ somewhat from those involved in speaking. As a result, some brain-damaged patients are good at language comprehension but poor at speaking, whereas others have the opposite pattern.

Second, cognitive neuropsychologists assume it is important to search for dissociations. A dissociation occurs when a brain-damaged patient performs at the same level as healthy individuals on one task but is severely impaired on a second task. For example, amnesic patients perform well on tasks involving short-term memory but have very poor performance on most long-term memory tasks (see Chapter 8). This suggests that short-term memory and long-term memory involve separate modules. However, it might be that brain damage reduces the ability to perform difficult (but not easy) tasks, and that long-term memory tasks are more difficult than short-term memory ones. Suppose, however, that we found other patients with very poor performance on most short-term memory tasks but intact long-term memory. We would then have a **double dissociation**: some patients performing at the same level as healthy individuals on task X but being impaired on task Y, with others showing the opposite pattern. This double dissociation provides strong evidence that there are separate short-term and long-term memory systems. Double dissociations have also provided support for the notion that there are two main routes in reading (Chapter 10).

There are various limitations with the cognitive neuropsychological approach. First, the organization of the human brain is far less neat and tidy than implied by cognitive neuropsychologists with their emphasis on modularity. As Banich (1997, p. 52) pointed out, "The brain is composed of about 50 billion *interconnected* neurons. Therefore, even complex cognitive functions for which a modular description seems apt rely on a number of interconnected brain regions or systems."

Second, cognitive neuropsychology is generally more comfortable dealing with relatively *specific* aspects of cognitive functioning, perhaps because more general aspects do not lend themselves readily to a modular account. For example, consider research on language. Much of it has been on the reading and spelling of individual words by brain-damaged patients, with little emphasis on broader issues concerned with the comprehension of texts or speech.

Third, it would be ideal to find patients in whom brain damage had affected only *one* module. However, brain damage is typically much more extensive than that. When several different processing modules or processors are damaged, it is generally difficult to interpret the findings.

> **Key Term**
>
> **Double dissociation:** the finding that some individuals (often brain-damaged) do well on task A and poorly on task B, whereas others show the opposite pattern.

COMPUTATIONAL COGNITIVE SCIENCE

The computational models developed by computational cognitive scientists can show us how a given theory may be specified in detail. This is a definite advantage over many previous theories in cognitive psychology, which were expressed so vaguely that it was unclear exactly what predictions followed from them. What that means is that theoretical inadequacies are easier to spot, and this can prompt the development of more adequate theories.

In recent years, connectionist networks have become very popular. **Connectionist networks** typically consist of elementary or neuron-like units or nodes connected together. They have different structures or layers (e.g., a layer of input links, intermediate layers, and a layer of output links). Within such networks, memories are distributed over the network rather than being in a single location.

Connectionist networks are popular because the numerous elementary units within a connectionist network superficially resemble the neurons in the brain. Another reason is that connectionist networks can to some extent program themselves and so "learn" to produce specific outputs when certain inputs are given to them. In spite of these promising features, connectionist networks fail to resemble the human brain (see Chapter 2). They typically use thousands or tens of thousands of connected units to model a task that might be performed by tens of millions of neurons in the brain.

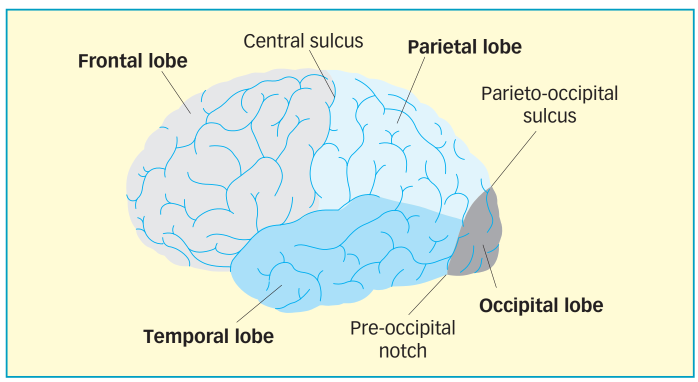
COGNITIVE NEUROSCIENCE

Technological advances mean we now have numerous new and exciting ways of obtaining detailed information about the brain's functioning and structure. We can work out *where* and *when* in the brain specific cognitive processes occur. Such information allows us to determine the order in which different parts of the brain become active when someone is performing a task. It also allows us to find out whether two tasks involve the same parts of the brain in the same way, or whether there are important differences.

Before discussing the techniques that have been developed, it is important to consider the brain in some detail. The cerebral cortex is divided into four main divisions or lobes (see the figure below). There are four lobes in each hemisphere: frontal; parietal; temporal; and occipital. The frontal lobes are divided from the parietal lobes by the central sulcus (*sulcus* means furrow or groove), and the parieto-occipital sulcus and the pre-occipital notch divide the occipital lobe from the parietal and frontal lobes.

For future reference, it is useful to know the meaning of various terms used to describe more precisely the brain area activated during the performance of some task. Some of the main terms are as follows:

- *dorsal*: superior or on top
- *ventral*: inferior or at the bottom
- *lateral*: situated at the side
- *medial*: situated in the middle.



The four lobes, or divisions, of the cerebral cortex in the left hemisphere.

Brief information concerning techniques for studying brain activity is contained in the box overleaf (fuller descriptions are given in Eysenck and Keane, 2005). Which technique is the best? There is no simple answer. Each technique has its own strengths and limitations, and so researchers focus on matching the technique to the issue they are addressing. The techniques vary in the precision with which they identify the brain areas active when a task is performed (spatial resolution) and the time course of such activation (temporal resolution). Thus, they differ in their ability to provide precise information concerning *where* and *when* brain activity occurs. The spatial and temporal resolutions of some of the main techniques are shown in the figure overleaf. High spatial and temporal resolutions are advantageous if a very detailed account of brain functioning is required. In contrast, low temporal resolution can be more useful if a general overview of brain activity during an entire task is needed.

Key Term

Connectionist networks: they consist of elementary units or nodes that are strongly interconnected; each network has various layers.

Major techniques used to study the brain

Single-unit recording: This technique involves inserting a micro-electrode one 10,000th of a millimeter in diameter into the brain to study activity in single neurons. This is a very sensitive technique.

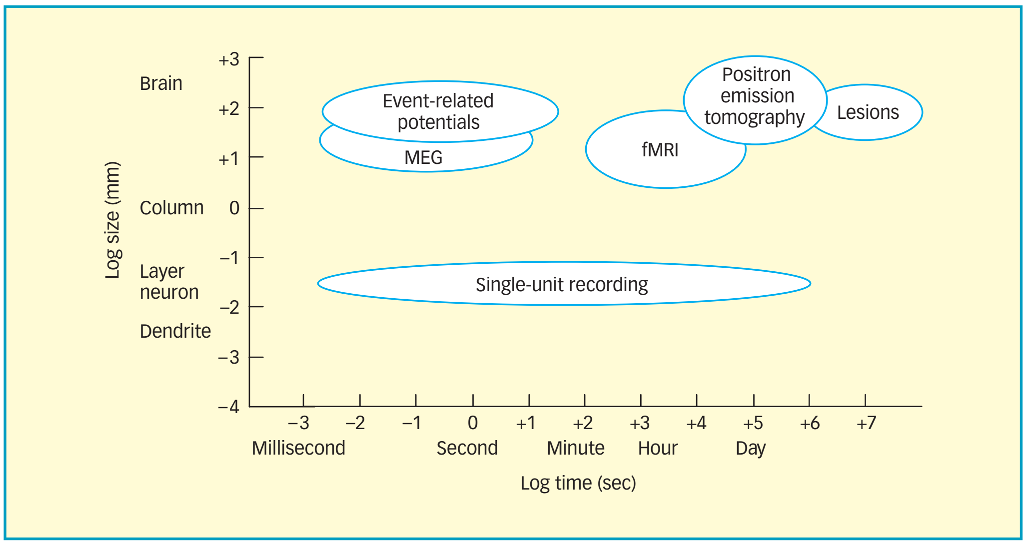
Event-related potentials (ERPs): The same stimulus is presented repeatedly, and the pattern of electrical brain activity recorded by several scalp electrodes is averaged to produce a single waveform. This technique allows us to work out the timing of various cognitive processes.

Positron emission tomography (PET): This technique involves the detection of positrons, which are the atomic particles emitted from some radioactive substances. PET has reasonable spatial resolution but poor temporal resolution, and it only provides an indirect measure of neural activity.

Functional magnetic resonance imaging (fMRI): This technique involves the detection of magnetic changes in the brain. fMRI has superior spatial and temporal resolution to PET, but provides only an indirect measure of neural activity.

Magneto-encephalography (MEG): This technique measures the magnetic fields produced by electrical brain activity. It provides fairly detailed information at the millisecond level about the time course of cognitive processes, and its spatial resolution is reasonably good.

Transcranial magnetic stimulation (TMS): This is a technique in which a coil (or pair of coils) is placed close to the participant's head and a large, very brief pulse of current is run through it. This produces a short-lived magnetic field, inhibiting processing in the brain area affected. This technique has (jokingly!) been compared to hitting someone's brain with a hammer (Johannes Zanker, personal communication).



The spatial and temporal ranges of some techniques used to study brain functioning. Adapted from Churchland and Sejnowski (1991).

Do brain-imaging techniques answer all our prayers? There are three reasons for skepticism. First, most brain-imaging techniques indicate only that there are *associations* between patterns of brain activation and behavior (e.g., performance on a reasoning task is associated with activation of the prefrontal cortex at the front of the brain). Such associations are essentially correlational. As Walsh and Rushworth (1999, p. 126) pointed out, "Mapping techniques record brain activity which is correlated with some behavioral event. But the correlations do not show that an area is necessary for a particular function." For example, suppose a given brain area x is activated when we solve a complex problem. We cannot be certain that important processes associated with problem solution occur in brain area x. It is possible that anxiety associated with thoughts of possible failure on the problem causes activation of that brain area, or the activation might reflect high motivation to solve the problem.

Second, numerous brain-imaging studies have lacked any clear theoretical basis. Far too often, researchers have merely found that some parts of the brain are activated during performance of a given task whereas others parts are not. Such findings are of no particular interest if not predicted on the basis of some theory. The good news is that there is a clear trend towards more and more brain-imaging studies being theoretically based.

Third, consider the colored maps you must have seen claiming to show which areas of the brain were activated when a given task was performed. In fact, all the colored areas are those where the amount of brain activity exceeded some threshold level determined by the experimenter. The problem is that the number of brain areas identified as active during performance of a task can vary wildly depending on the threshold level that is set (Savoy, 2001). To make matters worse, there are generally no very convincing arguments as to the appropriate setting of the threshold level.

Much progress has been made in addressing the limitations identified above, with researchers starting to move away from purely correlational data. For example, we can show that activity in a given area of the brain is necessary to perform a task effectively by using transcranial magnetic stimulation (TMS) (discussed in the box opposite). In essence, TMS involves applying pulses of current to some area of the brain, thus causing a "temporary lesion." Suppose you believed that brain area x was involved in performing a task. If TMS applied to that particular brain area led to impairment of task performance, we could conclude that that brain area is necessary for good task performance. On the other hand, if TMS applied to that brain area had *no* effect on task performance, we would conclude that that brain area is not needed to perform the task effectively.

A patient undergoing image-guided transcranial magnetic stimulation (TMS).

What about the criticism that brain-imaging studies contribute nothing to our theoretical understanding? That is less true now we have a reasonably clear idea of the kinds of processing associated with most brain areas. For example, we know that the early stages of visual perception involve Areas 17 and 18, both of which are in the occipital area of the cortex. Kosslyn (e.g., 1994) has argued that visual imagery involves the same processes as visual perception. We can thus predict that Areas 17 and 18 should be activated when people are engaged in visual imagery. To cut a long story short, visual imagery is often (but not always) associated with much activation in those brain areas (see Kosslyn and Thompson, 2003, for a review).

ORGANIZATION OF CHAPTERS 6–10

Everyone agrees that understanding fully how the brain works is one of the crucial scientific challenges of the twenty-first century. What is really exciting is that scientists finally have access to the technology and approaches needed to meet that challenge successfully. As a result, there has probably been more progress in understanding human cognition in the past decade than ever before, and the omens are favorable for the future.

Our current understanding of the major areas in cognitive psychology is discussed over the next five chapters. We start in Chapter 6 with a discussion of the processes involved in attention. We also consider some of the factors determining how well (or how badly!) we cope with trying to do two tasks at the same time. Finally, key processes involved in visual perception are discussed, including the crucial issue of how we manage to identify the objects in the world around us. Chapter 7 deals with learning, starting with traditional approaches based on conditioning and then moving on to more cognitive approaches involved in accounting for complex learning (e.g., acquisition of expertise). Chapter 8 deals with human memory, including short-term and long-term memory, and the processes involved in the storage and subsequent retrieval of information. Chapter 9 addresses the key area of thinking. The focus is on problem solving and decision making, with full consideration being given to the issue of whether our thinking is generally rational and logical. Finally, in Chapter 10, we consider the surprisingly complex processes involved in the comprehension and production of language.

Chapter 6

Contents

6

Visual perception and attention

Visual perception is of enormous importance to us in our everyday lives. It allows us to move around freely, to see other people, to read magazines and books, and to watch movies and television. It is very important for visual perception to be accurate—if we misperceive how close cars are to us as we cross the road, the consequences may be fatal. It is no coincidence that far more of the human cortex is devoted to vision than to any other sensory modality.

Visual perception seems so simple and effortless that we are in danger of taking it for granted. In fact, however, it is very complex. Supporting evidence comes from the efforts of researchers in artificial intelligence, who have tried to program computers to "perceive" the environment. As yet, no computer can match more than a fraction of the skills of visual perception possessed by nearly every adult human.

There are an enormous number of different aspects of visual perception, and we can only discuss a few of the most important ones here. First, we consider object recognition—how do we know we are looking at a cat or a tree? Second, we consider the theoretical assumption that we have two rather different visual systems. Strong evidence in support of this assumption has come from the study of visual illusions, and we focus mainly on that evidence. Third, we consider the assumption that visual perception is by its very nature conscious. In fact, there is reasonably convincing evidence that many perceptual processes occur below the level of conscious awareness, and that unconscious perception is a reality. Fourth, we consider the relationship between visual perception and attention. Our belief that we can see clearly the entire visual scene in front of us is incorrect. We only have a detailed awareness of those aspects of the visual scene to which we have paid attention, and rarely notice changes to unattended aspects.

Only visual perception is covered in this chapter. However, some aspects of auditory perception are discussed elsewhere in this book. For humans, a crucial use to which we put our auditory system is speech perception, and that is one of the main topics dealt with in Chapter 10.

The most obvious characteristic of attention is that it is *selective*—for example, we choose to attend to certain people or objects in the environment and more or less ignore everything else. It has been argued that visual attention is like a spotlight or a zoom lens focusing on a given area within the visual field. The strengths and limitations of these notions are considered. After that, there is coverage of auditory attention.

Finally, we consider an issue of great relevance in today's 24/7 world—how we cope with trying to do several things at the same time (often known as multitasking). As we will see, we are not as good at multitasking as we like to think.

OBJECT RECOGNITION

Something we all do tens of thousands of times every day is to identify or recognize objects in the world. At this very moment, you are aware that you are looking at a book (perhaps with your eyes glazed over!). If you raise your eyes, then perhaps you can see a wall, windows, and so on in front of you. I imagine you would agree with me that it seems incredibly easy to recognize common objects. In fact, there are powerful reasons for arguing that the processes involved in object recognition are actually far more complex than seems to be the case:

1. Many objects in the environment overlap with each other, so you have to decide where one object ends and the next one begins.
2. We can all recognize an object such as a chair without any apparent difficulty. However, chairs (and many other objects) vary enormously in their visual properties (e.g., color; size; shape), and it is not immediately clear how we assign such different stimuli to the same category.
3. We recognize objects accurately over a wide range of viewing distances and orientations. For example, most plates are round but we can still identify a plate when it is seen from an angle and so appears elliptical.

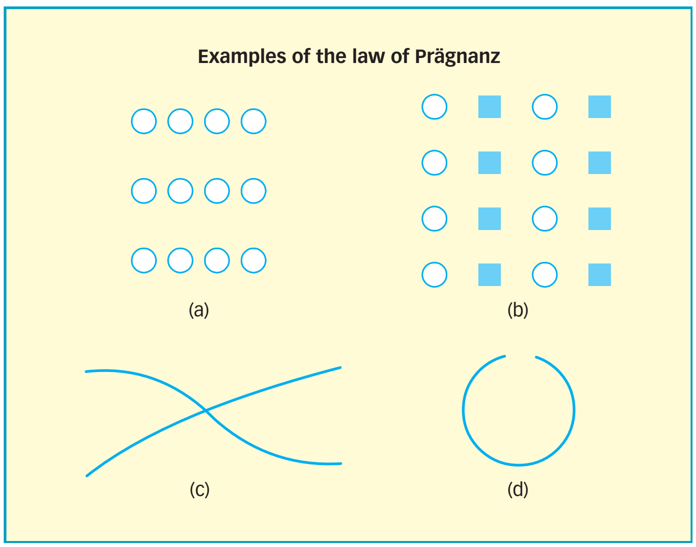
In sum, there is much more to object recognition than might initially be supposed (than meets the eye?). We turn now to some of the key processes involved.

Key Term

Figure–ground segregation: the perceptual organization of the visual field into a figure (object of central interest) and a ground (less important background).

PERCEPTUAL ORGANIZATION

A fundamental issue in visual perception is perceptual segregation, that is, our ability to work out accurately which parts of the visual information presented to us belong together and thus form objects. The Gestaltists (e.g., Koffka, Köhler, Wertheimer) studied perceptual segregation (and the perceptual organization to which it gives rise) in the early twentieth century. Their primary principle of perceptual organization was the law of Prägnanz: "Of several geometrically possible organizations that one will actually occur which possesses the best, simplest and most stable shape" (Koffka, 1935, p. 138).

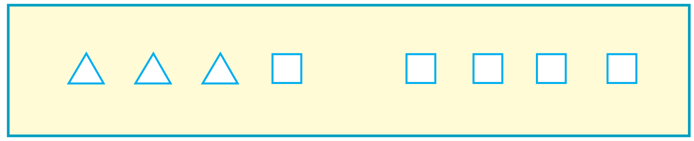


The Gestaltists proposed several other laws, but most of them are simply specific examples of the law of Prägnanz (see the figure on the left). The fact that three horizontal arrays of dots rather than vertical groups are seen in part (a) indicates that visual elements tend to be grouped together if they are close to each other (the law of proximity). Part (b) of the figure illustrates the law of similarity, which states that elements will be grouped together perceptually if they are similar. Vertical columns rather than horizontal rows are seen because the elements in the vertical columns are the same, whereas those in the horizontal rows are not. We see two crossing lines in part (c) of the figure because according to the law of good continuation we group together those elements requiring the fewest changes or interruptions in straight or smoothly curving lines. Finally, part (d) illustrates the law of closure, according to which missing parts of a figure are filled in to complete the figure. Thus, a circle is seen even though it is incomplete.

The Gestaltists emphasized the importance of **figure–ground segregation:** one object or part of the visual field is identified as the figure (central object) with the rest of the visual field forming the ground. The laws of perceptual organization permit this segregation into figure and ground to happen. According to the Gestaltists, the figure is seen as having a distinct form or shape, whereas the ground lacks form. In addition, the figure is perceived as being in front of the ground, and the contour separating the figure from the ground is seen as belonging to the figure.

The faces–goblet ambiguous figure is an example of figure and ground—which is figure and which is ground?

You can check the Gestaltists' claims about figure and ground by looking at reversible figures such as the faces–goblet figure (see the figure on the left). When the goblet is the figure, it seems to be in front of a dark background, whereas the faces are in front of a white background when forming the figure.



Display involving a conflict between proximity and similarity.

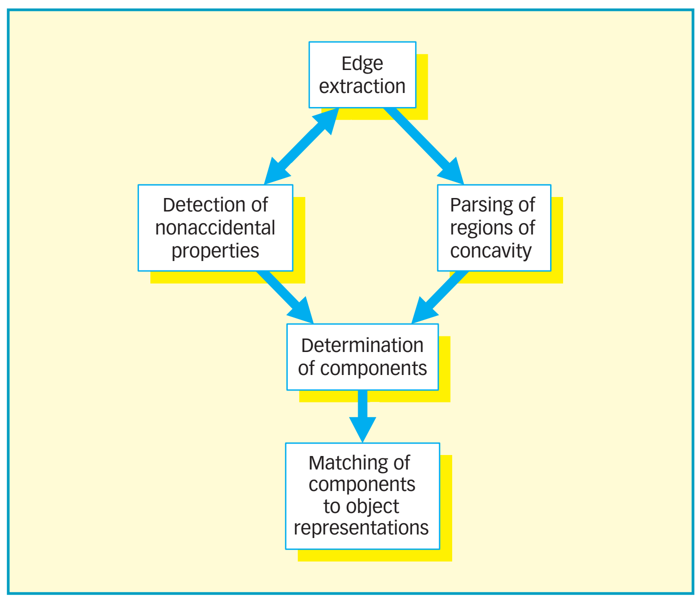
What are the limitations of the Gestaltist approach? First, the Gestaltists mostly studied *artificial* figures, and so their findings may not apply to more realistic stimuli. However, some reassurance was provided by Elder and Goldberg (2002). They presented pictures of natural objects, and found that observers used proximity as a cue when deciding which contours belonged to which objects. They also found that the cue of good continuation was used. Second, the Gestaltists' various laws provide a description of what happens but fail to explain *why* and *how* perceptual organization occurs. Third, the Gestaltists didn't focus enough on the complexities involved when different laws of grouping are in *conflict*. For example, consider a display such as the one used by Quinlan and Wilton (1998; see the figure above). How do you think most observers grouped the stimuli? About 50% grouped the stimuli by proximity and the remaining 50% by similarity. Alas, the Gestaltists didn't indicate how we can explain such individual differences!

OBJECT RECOGNITION: DOES VIEWPOINT MATTER?

Form a visual image of a bicycle. I expect your visual image involves a side view in which both bicycle wheels can be seen clearly. We can use this example to raise a controversial issue. Suppose some people saw a picture of a bicycle shown in the typical view as in your visual image, whereas other people were presented with a picture of the same bicycle viewed end on or from above. Both groups of people are instructed to identify the object as rapidly as possible. Would the group given the typical view of a bicycle perform this task faster than the other group?

The assumption that object recognition is faster and easier when objects are seen from certain angles is made by **viewpoint-dependent theories**. In contrast, the notion that object recognition is equally rapid and easy regardless of the angle from which an object is viewed is made by **viewpoint-invariant theories**. Tarr and Bülthoff (1995, 1998) put forward a viewpoint-dependent theory. According to them, we have observed most common objects from several different angles or perspectives. As a result, we have several stored views of such objects in long-term memory. Object recognition is easier when the view we have of an object corresponds closely to one of those stored views.

In contrast, Biederman's (1987) recognition-by-components theory is an example of the viewpoint-invariant approach. According to him, objects consist of basic shapes or components known as "geons" (geometric ions). Examples of geons are blocks, cylinders, spheres, arcs, and wedges. According to Biederman (1987), there are about 36 different geons, which can be arranged in almost endless different ways. For example, a cup can be described by an arc connected to the side of a cylinder, and a pail can be described by the same two geons but with the arc connected to the top of the cylinder. Object recognition depends primarily on the identification of geons. Since an object's geons can be identified from numerous viewpoints, object recognition should not depend on viewpoint provided that all of an object's geons are visible.



An outline of Biederman's recognition-by-components theory. Adapted from Biederman (1987).

Findings

It is easy in principle to compare the two theories. We simply present the same object from several viewpoints and record the time taken to identify it from each viewpoint. According to viewpoint-dependent theorists, the times should vary across viewpoints, whereas the times shouldn't

Key Terms

Viewpoint-dependent theories: theories of object recognition based on the assumption that objects can be recognized more easily from some angles than from others; see **viewpoint-invariant theories**.

Viewpoint-invariant theories: theories of object recognition based on the assumption that objects can be recognized equally easily from all angles; see **viewpoint-dependent theories**.

vary according to viewpoint-invariant theorists. In reality, the findings are somewhat inconsistent.

Biederman and Gerhardstein (1993) argued from their viewpoint-invariant theory that object naming should be facilitated as much by two different views of an object as by two identical views provided the same geon-based description could be constructed from both views. Their findings supported the prediction even when there was an angular difference of 135° between the two views. However, these findings are the exception rather than the rule.

Tarr and Bülthoff (1995) gave participants extensive practice at recognizing novel objects from certain specified viewpoints. What they found in each of several experiments was very consistent: "Response times and error rates for naming a familiar object in an unfamiliar viewpoint increased with rotation distance between the unfamiliar viewpoint and the nearest familiar viewpoint" (Tarr & Bülthoff, 1995, p. 1500). Thus, as predicted by viewpoint-dependent theories, it was easier to recognize objects presented from viewpoints that matched stored views.

The available evidence indicates that object recognition is sometimes viewpoint-dependent and sometimes viewpoint-invariant. Viewpoint-dependent mechanisms are most likely to be used when the task involves complex discriminations (e.g., between different makes of car), whereas viewpoint-invariant mechanisms are used when the task is easy (e.g., discriminating between trees and flowers). Supporting evidence was reported by Vanrie, Béatsie, Wagemans, Sunaert, and van Hecke (2002). Participants were presented with pairs of three-dimensional block figures in different orientations and had to decide whether they represented the same figure. There were two conditions differing in difficulty level. As predicted, object recognition was viewpoint-invariant in the simpler condition, but it was viewpoint-dependent in the harder condition.

Foster and Gilson (2002) proposed an alternative theoretical approach. According to them, viewpoint-dependent and viewpoint-invariant information is often combined. Participants had to decide whether two images of three-dimensional objects showed the same object or two different objects. The key finding was that participants used *both* kinds of information. This suggests we use *all* available information rather than confining ourselves to only some of it.

Evaluation

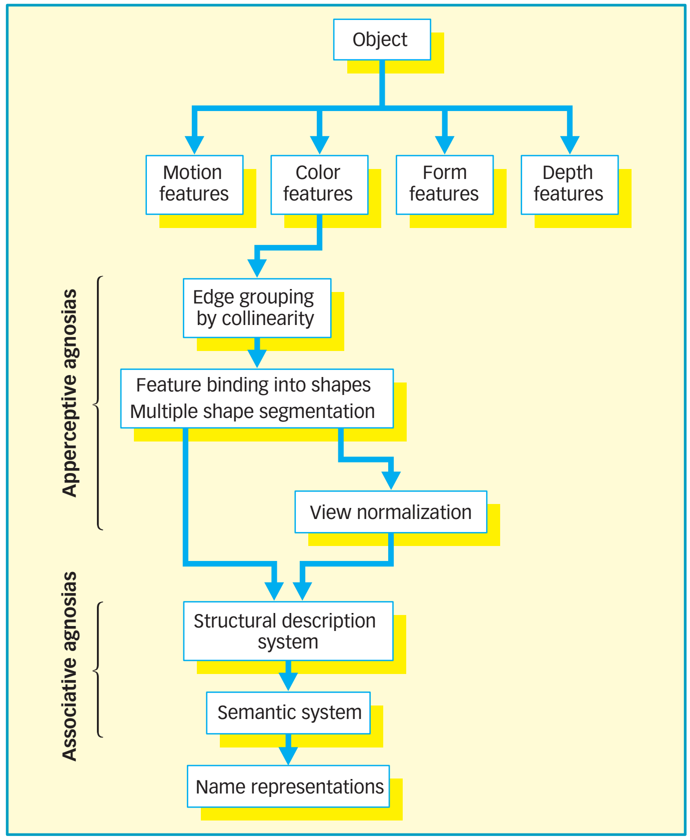
- (+) It has been established that object recognition is sometimes viewpoint-dependent and sometimes viewpoint-invariant.
- (+) There is an increasing understanding of the conditions in which object recognition is viewpoint-independent or viewpoint-invariant. For example, object recognition is much more likely to be viewpoint-invariant when the task is very easy than when it is complex and involves fine discriminations.
- (–) It is not altogether clear whether viewpoint-invariant and viewpoint-dependent information is generally combined during object recognition.
- (–) The theories put forward by Biederman (1987) and by Tarr and Bülthoff (1995) only address some of the key issues concerning object recognition. A more detailed approach to the processes underlying object recognition is discussed below.

FIVE PROCESSING STAGES

There has been much research on brain-damaged patients experiencing problems in object recognition. What is striking about this research is the enormous variety of problems they report. This suggests that there are several different stages of processing involved in object recognition, any one of which can be damaged. At each stage, more detailed information about visual objects is processed. Riddoch and Humphreys (2001) have provided a hierarchical model of object recognition (see the figure on the right) based on five stages or processes:

1. *Edge grouping by collinearity* (collinear means having a common line): This is an early stage of processing during which an object's edges are worked out.
2. *Feature binding into shapes*: During this stage, object features that have been extracted are combined to form shapes.
3. *View normalization*: During this stage, processing occurs to allow a viewpoint-invariant representation to be worked out.
4. *Structural description*: During this stage, individuals gain access to stored knowledge about the structural descriptions of objects (i.e., their overall form and shape).
5. *Semantic system*: The final stage in object recognition involves gaining access to stored knowledge of semantic information relating to an object.

What predictions follow from this model? The most obvious one is that there should be patients having problems in object recognition at each of the stages of processing identified in the model. As we will see, there is reasonable support for this prediction.



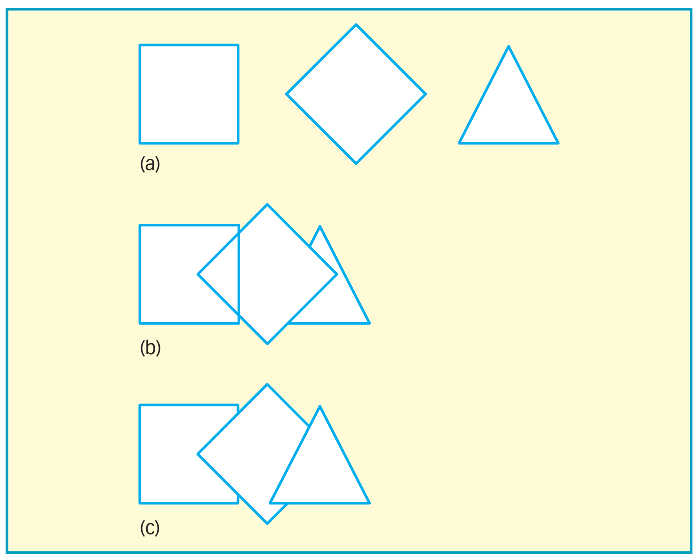
A hierarchical model of object recognition and naming, specifying different component processes which, when impaired, can produce varieties of apperceptive and associative agnosia. From Riddoch and Humphreys (2001).

Findings

Many patients have problems with edge grouping (stage 1). Milner et al. (1991) studied a patient, DF (discussed later in the chapter), who recognized only a few real objects and who couldn't recognize any objects shown in line drawings. She also had poor performance when making judgments about simple patterns grouped on the basis of various properties (e.g., proximity).

The most-studied patient having particular problems with feature binding (stage 2) is HJA. According to G.W. Humphreys (e.g., 1999), this patient suffers from **integrative agnosia**, a condition in which there are problems combining or integrating features of an object during recognition. Giersch, Humphreys, Boucart, and Kovacs (2000) presented HJA with an array of three geometric shapes that were spatially separated or superimposed or occluded (covered) (see the figure on the right). Then a second visual array was presented, which was either the original array or a distractor array in which the positions of the shapes had been re-arranged.

HJA performed reasonably well with separated shapes but not with superimposed or occluded shapes. Thus, he had poor ability for shape segregation.



Examples of (a) separated, (b) superimposed, and (c) occluded shapes used by Giersch et al. (2000). From Riddoch and Humphreys (2001).

Patients having problems with view normalization (stage 3) would find it hard to recognize that two objects are the same when viewed from different angles. Such findings were reported by Warrington and Taylor (1978). Patients were presented with pairs of photographs, one of which was a conventional or typical view and the other of which was an unusual view. For example, the usual view of a flat-iron was photographed from above, whereas the unusual view showed only the base of the iron and part of the handle. The task was to decide whether the same object was shown in both photographs. The patients performed poorly on this task, finding it hard to identify an object shown

Key Term

Integrative agnosia: a condition in which the patient experiences great difficulty in integrating features of an object when engaged in object recognition.

from an unusual angle even when they had already identified it from the accompanying usual view.

We turn now to patients having problems with structural descriptions (stage 4). Fery and Morais (2003) studied such a patient (DJ). In spite of his problems, several processes relating to object recognition were essentially intact. For example, he was correct on 93% of trials on a difficult animal-decision task requiring a decision as to which one out of various drawings was an animal. However, DJ recognized only 16% of common objects presented visually, indicating that he couldn't easily access information stored in memory about the structural descriptions of objects on the basis of visual information.

Finally, we turn to patients who find it difficult to gain access to relevant stored information about objects. Some of these patients suffer from **category-specific deficits**, meaning they have problems with certain semantic categories but not others. For example, many such patients have greater problems in identifying pictures of living than of nonliving things (see Martin & Caramazza, 2003). It is likely that the problems with object recognition experienced by patients with category-specific disorders center on accessing certain kinds of semantic knowledge about objects rather than on any of the earlier stages of processing.

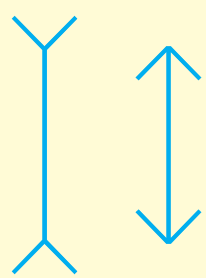
Key Term

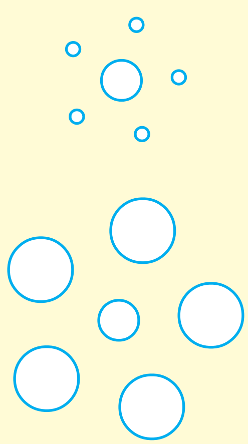
Category-specific deficits: disorders caused by brain damage in which patients have problems with some semantic categories but not with others.

Evaluation

- **+** Riddoch and Humphreys' (2001) model of object recognition provides a useful framework within which to consider the various problems with object recognition shown by brain-damaged patients.
- **+** There is evidence supporting each of the separate stages of edge grouping, feature binding, view normalization, structural descriptions, and access to semantic knowledge.
- **–** It is assumed that each stage of processing uses the output from the previous one, but precisely *how* this happens remains unclear.
- **–** It is assumed that processing in object recognition proceeds in an orderly way through five successive stages. In fact, the stored knowledge about structural descriptions and semantic information about objects associated with stages 4 and 5 often influences processing at earlier stages.

The Müller–Lyer illusion



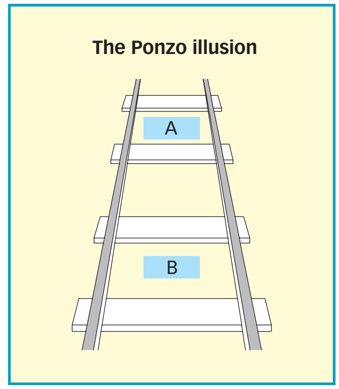


The Ebbinghaus illusion.

VISUAL ILLUSIONS: TWO SYSTEMS

When we look at the world around us, we are usually confident that what we see corresponds precisely to what is actually there. Indeed, the human species would probably have become extinct a very long time ago if we perceived the environment inaccurately. For example, if we thought the edge of a precipice was further away than was actually the case or that the jump from a wall to the ground was 3 feet (1 meter) when it was actually 9 feet (3 meters), then our lives would be in danger. In spite of these apparently persuasive arguments in favor of accurate visual perception, psychologists have found that we are subject to numerous visual illusions, a few of which are discussed below.

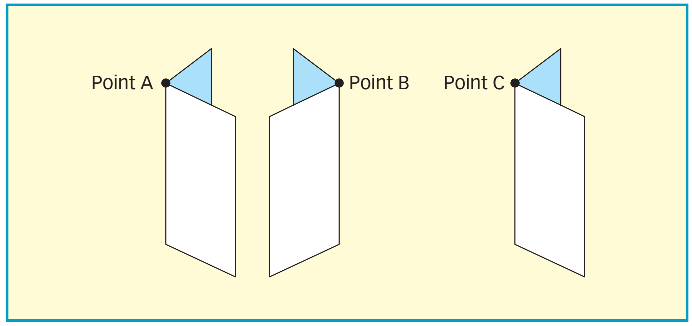
First, there is the Müller–Lyer illusion (see the figure on the left). Your task is to compare the lengths of the two vertical lines. Nearly everyone says that the vertical line on the left looks longer than the one on the right. In fact, however, they are the same length, as can be confirmed by using a ruler! Second, there is the Ebbinghaus illusion (see the figure on the left). In this illusion, the central circle surrounded by smaller circles looks larger than a central circle of the same size surrounded by larger circles. In fact, the two central circles are the same size. Third, there is the Ponzo illusion (see the figure on the right). In this illusion, the rectangle labeled A seems larger than the rectangle labeled B in spite of the fact that they are the same length.



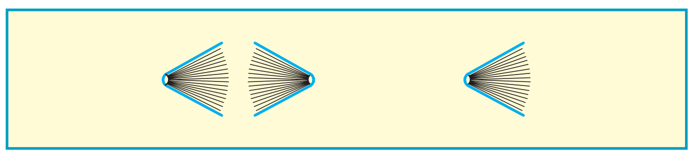
WHAT CAUSES VISUAL ILLUSIONS?

The existence of the Müller–Lyer, Ebbinghaus, and Ponzo illusions (plus many others) leaves us with an intriguing paradox. How has the human species been so successful given that our visual perceptual processes are apparently very prone to error? Consider your answer before reading on.

One plausible answer is that most visual illusions involve very artificial figures, and so can be dismissed as tricks played by psychologists with nothing better to do. There is some truth in this argument, but it doesn't account for all visual illusions. For example, you can show the Müller–Lyer illusion by following the lead of DeLucia and Hochberg (1991). They observed the typical Müller–Lyer effect when three 2-foot high fins were placed on the floor in an arrangement like that shown in the figure on the right. Place three open books in a line so that the ones on the left and the right are open to the right and the one in the middle is open to the left (see the figure below). The spine of the book in the middle should be the same distance from the spines of each of the other two books. However, the distance between the spine of the middle book and the spine of the book on the right will look longer.



In DeLucia and Hochberg's study, three fins that were 2 feet high were positioned on the floor and participants asked to say whether point A was closer to point B than B was to C. The Müller–Lyer illusion persists even though depth is obvious in this three-dimensional situation, a fact that does not fit Gregory's misapplied size-constancy theory.



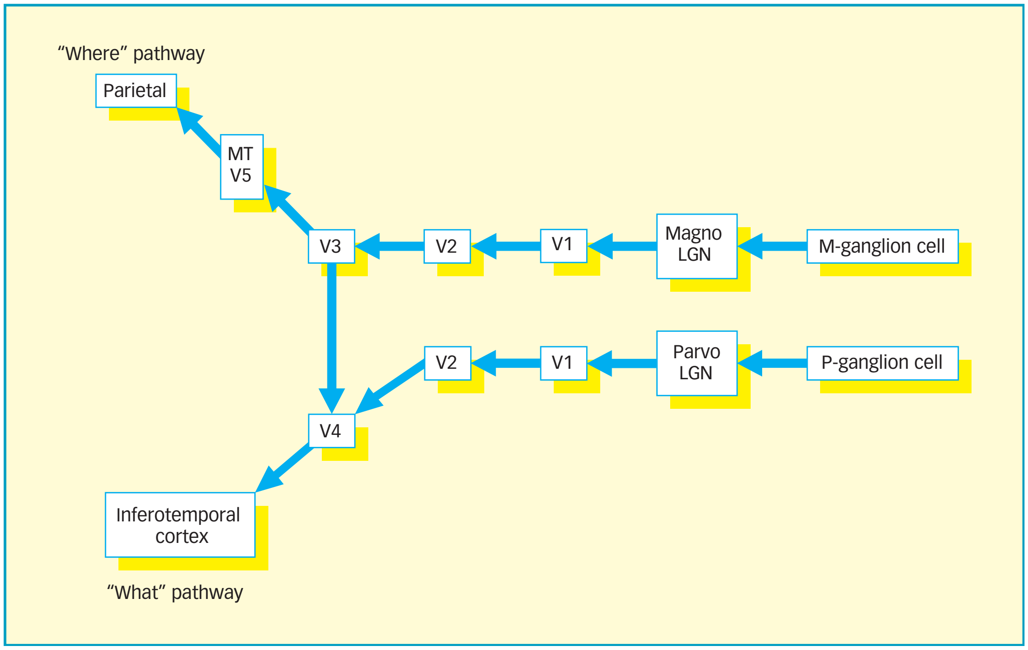
The spine of the middle book is closer to the spine of which other book? Now check your answer with a ruler.

Two visual systems

The most successful explanation of the paradox that visual perception can be error-prone in the laboratory in spite of being very accurate in everyday life was proposed by Milner and Goodale (1995, 1998). Their starting point was the startling assumption that we basically have *two* visual perceptual systems! In crude terms, one system allows us to move safely around our environment without knocking into objects or falling over precipices, whereas the other system is used to recognize objects and to perceive visual illusions. These two systems generally operate together but can function fairly independently. One of these systems (the vision-for-perception system) is used to make sense of the visual illusions, whereas the other system (the vision-for-action system) is used to move around the environment rapidly and safely.

We will now consider the two visual systems in more detail. The vision-for-perception system is what we immediately think of when considering visual perception. It is the system used to decide that the animal in front of us is a cat or a buffalo or to admire the paintings of Cézanne. More generally, this is the system allowing us to construct an internal model of the world. In contrast, the vision-for-action system is used for visually guided action. It is the system we use when running to return the ball when playing tennis or some other sport. We are not consciously aware that two systems are involved in visual perception and action, but our conscious experience is a fallible guide to what is actually happening.

Much evidence supports the perception–action approach of Milner and Goodale (1995, 1998). If there are two visual systems, they should involve different parts of the brain. Progress has been made in identifying the parts of the brain associated with each visual system (see the figure on the following page). Both visual systems start in V1, which is concerned with early visual processing. After that, however, the visual system involved in object recognition (based on a ventral pathway) projects to the inferotemporal cortex, whereas the visual stream involved in the guidance of action (based on a dorsal pathway) projects to the posterior parietal cortex.



A very simplified illustration of the pathways and brain areas involved in vision. There is much more interconnectivity within the brain (V1 onwards) than is shown, and there are additional unshown brain areas involved in vision. Adapted from Goldstein (1996).

How can we test this theory with visual illusions? Suppose we carried out studies on the visual illusions so that participants would use the vision-for-action system rather than the vision-for-perception system. We could do this by using three-dimensional versions of the illusions and instructing participants to reach for a key object (e.g., one of the central circles in the Ebbinghaus illusion). Milner and Goodale (1995, 1998) argued that this system should generally *not* be deceived by the visual illusions. If illusions present when the vision-for-perception system is used disappear when the vision-for-action system is used, this would provide strong support for the theoretical approach.

The relevant evidence mostly provides general support for the theory (see Glover, 2004, for a review). For example, Aglioti, Goodale, and DeSouza (1995) constructed a three-dimensional version of the Ebbinghaus illusion, and obtained the usual illusion effect when observers reported on the apparent size of the central disk. However, when observers reached to pick up one of the central disks (and so used the vision-for-action system), the maximum grip aperture of their reaching hand was almost entirely determined by the actual size of the disk. Thus, the illusion disappeared under these conditions.

Haart, Carey, and Milne (1999) used a three-dimensional version of the Müller–Lyer illusion (see the figure on p. 139). The usual illusion effect was found when observers had to indicate the apparent length of each vertical shaft. However, there was no illusion effect at all when they used the vision-for-action system to grasp one of the figures lengthwise using their index finger and thumb.

According to Milner and Goodale's perception–action model, we are generally not deceived by visual illusions when we respond to them with our vision-for-action system. However, matters are more complex than that. Glover (2004) reviewed the evidence. He discovered that people's *initial* hand movements towards illusion figures are often influenced by the illusion even though their hand movements thereafter become progressively more accurate as they approach it. Glover accounted for such findings by arguing that the production of human action involves two systems: a planning system and a control system. The planning system is involved in deciding how to grasp an object and is used mainly before a hand movement starts. In contrast, the control system is used in ensuring that movements are accurate and in making adjustments if required. It operates during the carrying out of a movement. According to this model, the planning system is affected by visual illusions but the control system is not.

Cognitive neuropsychology

The notion that there are two somewhat separate visual systems (one specialized for perception and one for action) can also be investigated by studying brain-damaged patients. We would expect to find some patients (those with damage to the dorsal stream) having reasonably intact vision for perception but severely impaired vision for action. There should be other patients (those with damage to the ventral stream) who show the opposite pattern.

We start by considering patients with **optic ataxia**, a condition in which reasonable visual perception is accompanied by problems with visually guided reaching. Perenin and Vighetto (1988) found that patients with optic ataxia had great difficulty in rotating their hands appropriately when given the task of reaching towards and into a large oriented slot in front of them. As expected, such patients typically have damage in parts of the posterior parietal lobe forming part of the dorsal pathway.

Glover (2004) reviewed evidence indicating that most patients with optic ataxia don't actually have problems with *all* aspects of reaching for objects. According to Glover, optic ataxia primarily involves deficits in the control system rather than in the planning system. For example, Jakobson et al. (1991) studied VK, a patient with optic ataxia who had difficulty in grasping objects. Close inspection of her grip aperture at different points in grasping indicated that her initial planning was essentially intact.

What about patients with deficient vision for perception but intact vision for action? Some patients with visual agnosia fit this pattern. **Visual agnosia** is a condition involving severe problems with object recognition. DF is the most studied patient having visual agnosia coupled with fairly good spatial perception. Dijkerman, Milner, and Carey (1998) assessed DF's performance on various tasks when presented with several differently colored objects. DF showed good vision for action in that she reached out and touched the objects as accurately as healthy individuals. However, she had poor vision for perception. She couldn't copy the objects in their correct spatial positions, and couldn't distinguish accurately between the colored objects.

According to Milner and Goodale's perception–action model, DF's brain damage should be in the ventral stream underlying object recognition rather than in the ventral

Key Terms

Optic ataxia:
a condition involving brain damage in which the patient has difficulty in making visually guided movements in spite of having reasonably intact visual perception.

Visual agnosia:
a condition in which there are great problems in recognizing objects presented visually even though visual information reaches the visual cortex.

Case Study: *The Man Who Mistook His Wife for a Hat*

Mr. P was "a musician of distinction, well-known for many years as a singer, and then at the local School of Music, as a teacher. It was here, in relation to his students, that certain strange problems were first observed. Sometimes a student would present himself, and Mr. P would not recognize him; or specifically, would not recognize his face. The moment the student spoke, he would be recognized by his voice. Such incidents multiplied, causing embarrassment, perplexity, fear—and, sometimes, comedy."

"At first these odd mistakes were laughed off as jokes, not least by Mr. P himself . . . His musical powers were as dazzling as ever; he did not feel ill . . . The notion of there being 'something the matter' did not emerge until some three years later, when diabetes developed. Well aware that diabetes could affect his eyes, Mr. P consulted an ophthalmologist, who took a careful history, and examined his eyes closely. 'There's nothing the matter with your eyes,' the doctor concluded. 'But there is trouble with the visual parts of your brain. You don't need my help, you must see a neurologist.' "

And so Mr. P went to see Oliver Sacks who found him quite normal except for the fact that, when they talked, Mr. P faced him with his *ears* rather than his eyes. Another episode alerted Sacks to the problem. He asked Mr. P to put his shoe back on.

" 'Ach,' he said, 'I had forgotten the shoe,' adding *sotto voce*, 'The shoe? The shoe?' He seemed baffled.

He continued to look downwards, though not at the shoe, with an intense but misplaced concentration. Finally his gaze settled on his foot: 'That is my shoe, yes?'

Did he mis-hear? Did he mis-see?

'My eyes,' he explained, and put his hand to his foot. '*This* is my shoe, no'

'No that is not. That is your foot. *There* is your shoe.'

'Ah! I thought it was my foot.'

Was he joking? Was he mad? Was he blind?"

Oliver Sacks helped Mr. P put on his shoe and gave him some further tests. His eyesight was fine, for example he had no difficulty seeing a pin on the floor. But when he was shown a picture of the Sahara desert and asked to describe it, he invented guesthouses, terraces, and tables with parasols. Sacks must have looked aghast but Mr. P seemed to think he had done rather well and decided it was time to end the examination. He reached out for his hat, and took hold of his wife's head, and tried to lift it off. He apparently had mistaken his wife's head for his hat.

The condition Mr. P suffered from is called visual agnosia and results from brain damage of some kind.

Adapted from Sacks (1985).

stream underlying vision for action. James et al. (2003) carried out a brain-imaging study on DF and obtained findings consistent with prediction.

Evaluation

- (+) There is much evidence from healthy individuals supporting the notion of two visual systems: vision-for-perception and vision-for-action.
- (+) Milner and Goodale's perception–action model provides an explanation of why there is often no illusion effect when people grasp three-dimensional visual illusions.
- (+) Patients with optic ataxia and visual agnosia support the model in general terms by showing that one visual system can be reasonably intact even though the other visual system is severely damaged.
- (−) The vision-for-action system is more complicated than implied by the perception–action model. It consists of a planning system and a control system, with the former being deceived by visual illusions.
- (−) The two visual systems interact in complex ways that are poorly understood.

UNCONSCIOUS PERCEPTION

Most people assume that visual perception is a conscious process in that we are consciously aware of the object or objects at which we are looking. If that is the case, then there is no such thing as **unconscious perception**, in which perception occurs in the absence of conscious awareness. Before we proceed, ask yourself whether you think that unconscious perception exists.

SUBLIMINAL PERCEPTION

The case for unconscious perception apparently received strong support from the notorious "research" carried out in 1957 by James Vicary, who was a struggling market researcher. He claimed to have flashed the words EAT POPCORN and DRINK COCA-COLA for 1/300th of a second (well below the threshold of conscious awareness) numerous times during showings of a movie called *Picnic* at a cinema in Fort Lee, New Jersey. A grand total of 45,699 people allegedly received these messages over a 6-week period. The power of unconscious perception was apparently shown in the finding that there was an increase of 18% in the cinema sales of Coca-Cola and a 58% increase in popcorn sales. Alas, Vicary admitted in 1962 that the study was a fabrication. Trappery (1996) combined data from 23 studies and found that stimuli presented below the conscious threshold had little or no effect on consumer behavior.

The finding that stimuli below the level of conscious awareness (**subliminal stimuli**) don't influence buying behavior doesn't mean that such stimuli have *no* effect. How can we decide whether an observer is consciously aware of a given visual stimulus? Merikle, Smilek, and Eastwood (2001) argued that there is an important distinction between two criteria or thresholds:

1. *Subjective threshold*: This is defined by an individual's failure to report conscious awareness of a stimulus, and is the most obvious measure to use.
2. *Objective threshold*: This is defined by an individual's inability to make an accurate forced-choice decision about a stimulus (e.g., guess at above-chance level whether it is a word).

The objective threshold is more stringent than the subjective threshold. As a result, observers often show "awareness" of a stimulus assessed by the objective threshold even

Key Terms

Unconscious perception: perception occurring below the level of conscious awareness.

Subliminal stimuli: these are stimuli presented below the level of conscious awareness.

when it doesn't exceed the subjective threshold. What should we do in these circumstances? The objective threshold may seem unduly stringent, but many psychologists argue that it is more valid than reliance on people's possibly inaccurate or distorted reports of their conscious experience. What is indisputable is that evidence for subliminal perception based on the objective threshold is more convincing than evidence based on the subjective threshold.

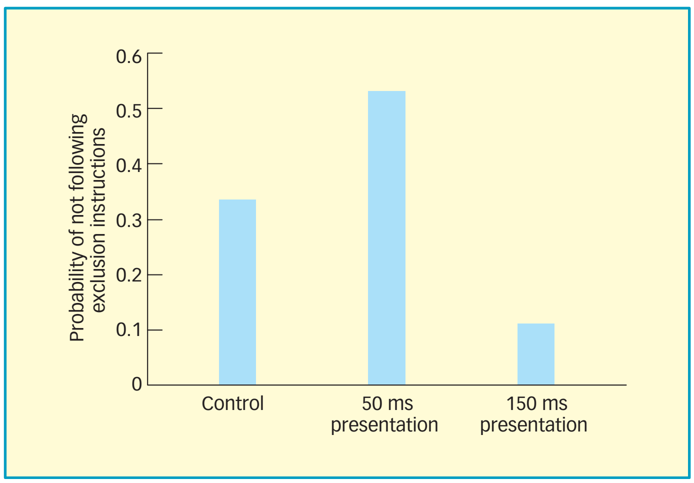
Findings

Dehaene et al. (1998) carried out an experiment using the objective threshold in which they initially showed that observers couldn't distinguish between trials on which a masked digit (subliminal stimulus) was or was not presented very briefly. After that, observers were presented on each trial with a masked digit followed by a clearly visible target digit—their task was to decide whether this target digit was larger or smaller than 5. The masked digit was either *congruent* with the target digit (both numbers on the same side of 5) or *incongruent*. Performance was slower on incongruent trials than on congruent ones, showing that information from the masked digit had been processed.

Snodgrass, Bernat, and Shevrin (2004) combined the data from nine published studies to assess the strength of the evidence for unconscious perception at the objective threshold. They obtained highly significant evidence of above-chance performance on measures designed to assess unconscious perception. In a further analysis, they found no significant evidence of above-chance performance on measures of conscious perception. Thus, they reported strong evidence for the existence of subliminal perception.

An alternative approach is to show that the effects of subliminal perception are very *different* from those of typical conscious perception rather than merely being weaker. This approach was adopted by Debner and Jacoby (1994). They assumed that information perceived with awareness permits us to control our actions, whereas information perceived without awareness does not. They tested these assumptions by presenting observers with a word for either 50 ms (subliminal stimulus) or 150 ms (consciously perceived stimulus) followed by a mask. Immediately after that, the first three letters of the word were presented again, and observers were instructed to think of the first word coming to mind starting with those letters *except* for the word that had just been masked (exclusion condition). There was also a control condition in which each word stem was preceded by an unrelated word.

When the masked word was presented for 150 ms, the participants followed instructions to avoid using that word on the word-stem completion task (see figure on the right). They perceived the masked word consciously, and so deliberately avoided using it. In contrast, when the masked word was presented for only 50 ms, it was often used to complete the word (see figure on the right). Limited processing of the masked word below the conscious level automatically triggered activation of its representation in memory and made it accessible on the word-stem completion task.



Probability of not following exclusion instructions in control (no relevant preceding word), 50 ms word presentation, and 150 ms word presentation conditions. Based on data in Debner and Jacoby (1994).

BLINDSIGHT

An army doctor by the name of Riddoch treated numerous British soldiers in the First World War who had received head injuries in battle. Those with damage to the primary visual cortex (involved in the early stages of visual processing) often had a loss of conscious perception in some parts of the visual field. What fascinated Riddoch (1917) was that some of these patients could still detect motion in those parts of the visual field in which they claimed to be blind! Brain-damaged patients having some visual perception in the absence of any conscious awareness are said to have **blindsight**, which neatly captures the apparently paradoxical nature of their condition.

Key Term

Blindsight: the ability of some brain-damaged patients to respond appropriately to visual stimuli in the absence of conscious visual perception.

What perceptual abilities do blindsight patients show in the parts of the visual field for which they have no conscious perceptual experience? According to Farah (2001, p. 162), "Detection and localization of light, and detection of motion are invariably preserved to some degree. In addition, many patients can discriminate orientation, shape, direction of movement, and flicker. Color vision mechanisms also appear to be preserved in some cases."

The phenomenon of blindsight becomes less paradoxical if we consider its assessment in more detail. The experimenter typically obtains two measures: (1) patients' subjective reports that they cannot see some stimulus presented to their blind region, and (2) patients' performance on a forced-choice test in which they have to guess (e.g., stimulus present or absent?) or point at the stimulus they cannot see. These measures are very different. In addition, performance on the forced-choice test (although significantly above chance level) is nevertheless way below the performance of normally sighted individuals.

Evidence that blindsight does not depend on conscious visual experience was reported by Rafal et al. (1990). Blindsight patients performed at chance level when given the task of detecting a light presented to the blind area of the visual field. However, their speed of reaction to a light presented to the intact part of the visual field was slowed down when a light was presented to the blind area at the same time. Thus, a light that didn't produce any conscious awareness nevertheless received enough processing to disrupt visual performance on another task.

Evaluation

- (+) Numerous studies on healthy individuals and blindsight patients have obtained evidence for the existence of subliminal perception.
- (+) Some of the most convincing evidence for subliminal perception comes from studies on healthy individuals either using the objective criterion or showing that the effects of conscious and unconscious perception can be very different.
- (−) It is difficult to be certain that any given individual has no conscious visual experience of a rapidly presented stimulus.
- (−) The reports of blindsight patients sometimes suggest there is residual conscious experience. According to Weiskrantz, Barbur, and Sahraie (1995), this visual experience is characterized by "a contentless kind of awareness, a feeling of something happening, albeit not normal seeing."

Key Term

Inattentional blindness: failure to detect an unexpected object appearing in a visual display; see **change blindness**.

Frame showing a woman in a gorilla suit in the middle of a game of passing the ball. From Simons and Chabris (1999). Copyright © Daniel J. Simons. Figure provided by Daniel Simons.

CHANGE BLINDNESS

Suppose you watch a film in which students are passing a ball to each other. At some point a woman in a gorilla suit walks right into camera shot, looks at the camera, thumps her chest, and then walks off. Altogether she is on the screen for 9 seconds. Are you very confident that you would spot the woman dressed up as a gorilla almost immediately? Of course you are! In fact, Simons and Chabris (1999) carried out an experiment along the lines just described (see the photo on the left). What percentage of their participants failed to spot the gorilla? Think about your answer before reading on.

It seems reasonable to assume that under 5% (or even under 1%) of people would fail to notice a gorilla taking 9 seconds to stroll across a scene. In fact, however, 50% of observers didn't notice the woman's presence! This phenomenon is known as **inattentional blindness**, defined as the failure to notice an unexpected object appearing in a visual display. We will consider possible explanations for this finding shortly.

In another experiment, Levin and Simons (1997) showed participants various videos involving two people having a conversation in a restaurant. In one video, the plates on their table change from red to white, and in another a scarf worn by one of them disappears. A third video showed a man sitting in his office and then walking into the hall to answer the phone. When the view switches from the office to the hall, the first person has been replaced by another man wearing different clothes. Levin and Simons (1997) found that no participants detected any of the changes. This phenomenon is known as **change blindness**, defined as a failure to detect that an object has moved or disappeared.

Levin, Drivdahl, Momen, and Beck (2002) obtained convincing evidence that we greatly underestimate our proneness to change blindness. They showed participants the videos used by Levin and Simons (1997) and asked them to indicate whether they thought they would have noticed the changes if they had not been forewarned about them. The percentages claiming they would have noticed the changes were as follows: 78% for the disappearing scarf; 59% for the changed man; and 46% for the change in color of the plates. Levin et al. (2002) used the term **change blindness blindness** to describe the wildly optimist belief in our ability to detect visual changes.

Our woefully mistaken belief that we perceive and remember nearly everything about us is good news for those who make movies and for conjurors. So far as movies are concerned, change blindness means that we rarely spot visual changes when the same scene has been shot more than once with parts of each shot being combined in the finished version of the movie. I will take the risk of appearing nerdy by providing two examples. In *Grease*, while John Travolta is singing "Greased Lightning," his socks change color several times between black and white. In the movie *Diamonds Are Forever*, James Bond tilts his car on two wheels to drive through a narrow alleyway. As he enters the alleyway, the car is balanced on its *right* wheels, but when it emerges on the other side it is miraculously on its *left* wheels!

How do conjurors and magicians capitalize on the phenomenon of change blindness blindness? In essence, most tricks involve **misdirection**, in which the conjuror or magician directs spectators' attention away from some action crucial to the success of the trick. Jakobsen (2004) discussed various ways of misdirecting an audience, of which we consider two. First, if magicians make a larger and a smaller movement at the same time, spectators will attend to the larger movement. As a result, conjurors can prepare the trick with the smaller movement. Second, spectators will typically look wherever the magician is looking. That means magicians can direct spectators' attention away from the crucial action they want to perform.

FACTORS INFLUENCING CHANGE BLINDNESS AND INATTENTIONAL BLINDNESS

The extent to which observers show change blindness and inattentional blindness depends on several factors. One factor is whether or not observers are aware beforehand that something is going to change. Observers are much more likely to show change blindness or inattentional blindness when they not informed of any possible change (see Simons and Rensink, 2005, for a review). For example, nearly 100% of observers would probably have detected the gorilla in the study by Simons and Chabris (1999) if they had been instructed beforehand to look out for something unexpected. Indeed, observers who watched the film a second time were very surprised they had missed the gorilla on first viewing!

A second factor determining whether change blindness or inattentional blindness occurs is the *similarity* between an unexpected object and other objects in the visual display. You will remember the surprising finding of Simons and Chabris (1999) that 50% of observers failed to detect a woman dressed in black as a gorilla. In that experiment, observers counted the number of passes made by members of the team dressed in white. The dissimilarity in color between the unexpected stimulus (gorilla) and the task-relevant stimuli (members of attended team) probably played a part in producing so much inattentional blindness. This was confirmed by Simons and Chabris (1999) in another

Key Terms

Change blindness: failure to detect changes in the visual environment.

Change blindness blindness: people's mistaken belief that they would notice visual changes that are in fact very rarely detected.

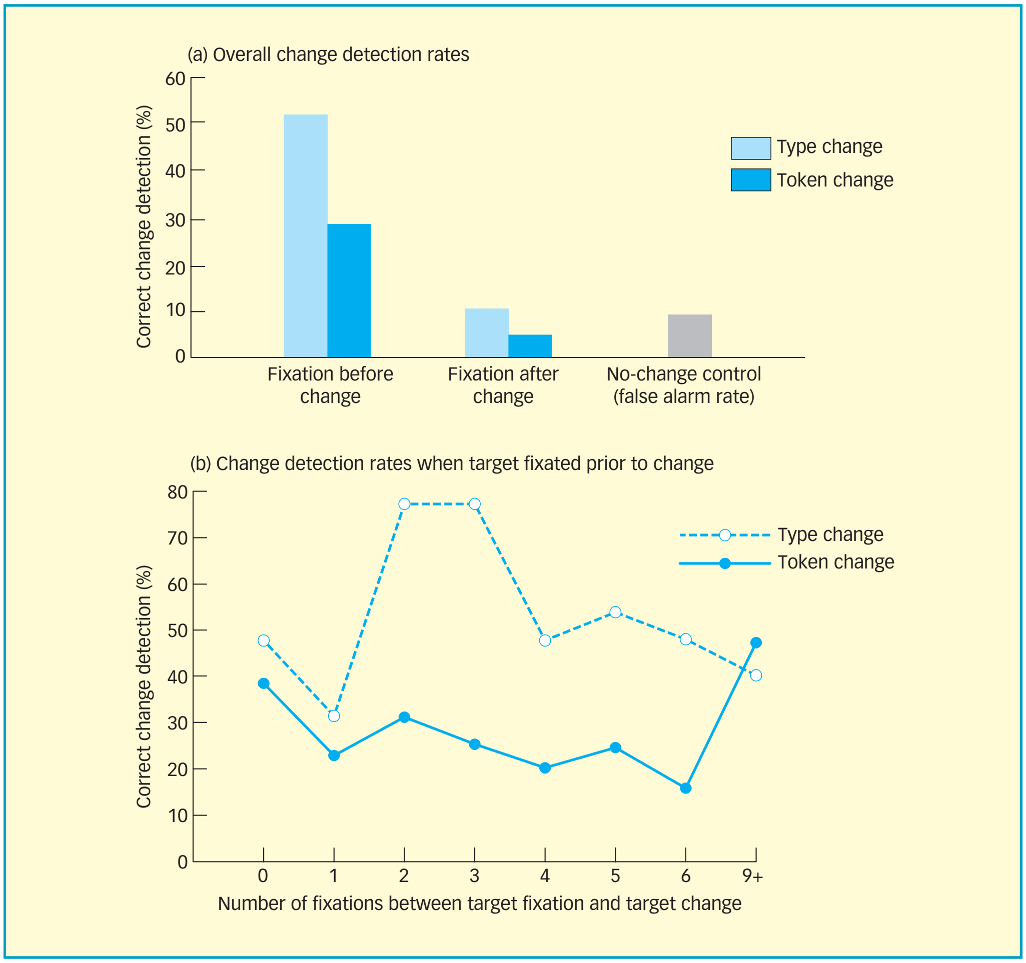
Misdirection: the various techniques used by magicians to make spectators focus on some irrelevant aspect of the situation while they perform the crucial part of a trick.

experiment in which observers counted the passes of the team dressed in white or the team in black. The gorilla's presence was detected by 83% of observers when the attended team was dressed in black compared to only 42% when it was dressed in white.

A third factor influencing change blindness is whether the object that changes has been attended to prior to the change occurring. Hollingworth and Henderson (2002) pointed out that there is an important distinction between two kinds of change to an object:

1. Type change, in which an object is replaced by an object from a different category (e.g., a plate is replaced by a bowl).
2. Token change, in which an object is replaced by an object from the same category (e.g., one plate is replaced by a different plate).

Token changes are smaller and less obvious than type changes, and so we would predict there would be more change blindness with token changes.



(a) Percent correct change detection as a function of form of change (type vs. token) and time of fixation (before vs. after change); also false alarm rate when there was no change. (b) Mean percent correct change detection as a function of the number of fixations between target fixation and change of target and form of change (type vs. token). From Hollingworth and Henderson (2002). Copyright © 2002 by the American Psychological Association. Reprinted with permission.

The key findings of Hollingworth and Henderson (2002) are shown in the figure above. Changes in objects were much more likely to be detected when the changed object had received attention (been fixated) beforehand. In addition, change detection was much better when there was a type change rather than a token change.

WHAT CAUSES CHANGE BLINDNESS?

Hollingworth and Henderson (2002) provided an explanation for change blindness. According to them, we form fairly detailed (but not very detailed) visual representations of objects that are the focus of attention. These representations are fitted into a mental map providing a spatial layout of the overall visual scene. Information about these visual representations and about the overall spatial layout is stored in long-term memory. Information about nonattended objects is typically not stored in long-term memory, and so we have very limited ability to detect changes in nonattended objects.

If reasonably detailed information about visual scenes is stored in long-term memory, it follows that observers should retain some memory of objects they fixated and attended to several minutes earlier. This prediction was tested by Hollingworth and Henderson (2002). Between 5 and 30 minutes after viewing various scenes, observers were presented with two scenes:

1. The original scene with a target object marked with a green arrow.
2. A distractor scene identical to the original scene except that there was a different object in the location of the target object.

The observers decided which was the original object. Overall, 93% of type changes were detected as well as 81% of token changes.

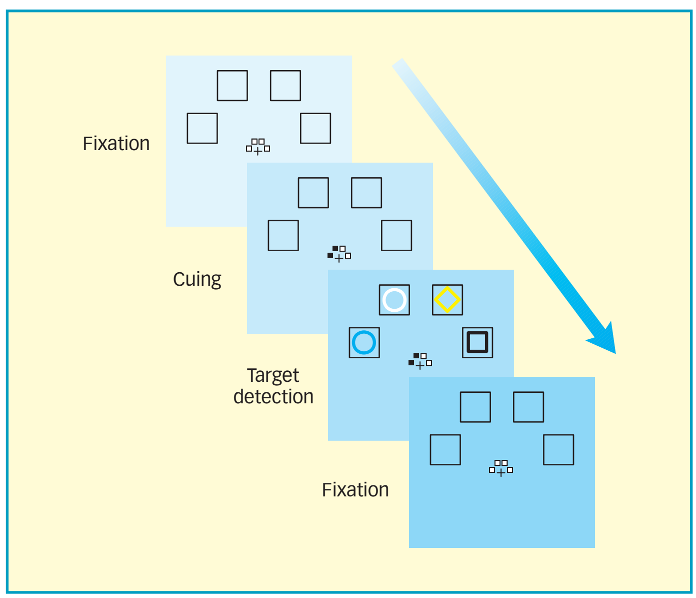
So far we have seen that people have a remarkably impressive ability to detect certain kinds of changes to a visual scene even when 30 minutes intervene between seeing the original scene and the changed one. However, Hollingworth and Henderson (2002) argued that the information stored in long-term memory about visual scenes is not very detailed. Henderson and Hollingworth (2003) presented observers with complex real-world scenes in which half of each scene was hidden by vertical gray bars. The entire scene changed whenever the observer's gaze crossed either of two invisible vertical lines so that the previously visible parts of the scene were hidden and the hidden parts became visible. Even though the observers knew the precise nature of the changes that might occur, they detected only 2.7% of them.

In sum, our belief that we have a clear and detailed representation of our visual environment is exaggerated but not entirely incorrect. What we actually have is a fairly clear and detailed representation of those parts of the visual environment to which we have recently paid attention. Change blindness is especially likely to be found when the changed part of the visual scene hasn't previously been the focus of attention.

VISUAL ATTENTION

What is attention? According to Colman (2001, p. 62), attention is "sustained concentration on a specific stimulus, sensation, idea, thought, or activity." Try focusing your attention on the world around you. As James (1890) pointed out, you probably found yourself attending to one object at a time or at one part of the visual space around you. Several psychologists (e.g., Posner, 1980) have argued that visual attention is like a spotlight: it illuminates a small part of the visual field, little can be seen outside its beam, and it can be re-directed flexibly to focus on any object of interest. Other psychologists (e.g., Eriksen & St. James, 1986) developed the notion of an attentional beam by comparing focused attention to a zoom lens. The basic idea is that we can increase or decrease the area of focal attention at will in the same way that a zoom lens can be moved in or out to alter the visual area it covers. This makes sense. For example, when driving a car it is typically desirable to attend to as much of the visual field as possible to anticipate danger. In contrast, when we come upon an unexpected phrase when reading, we narrow our attention to that phrase and try to make sense of it.

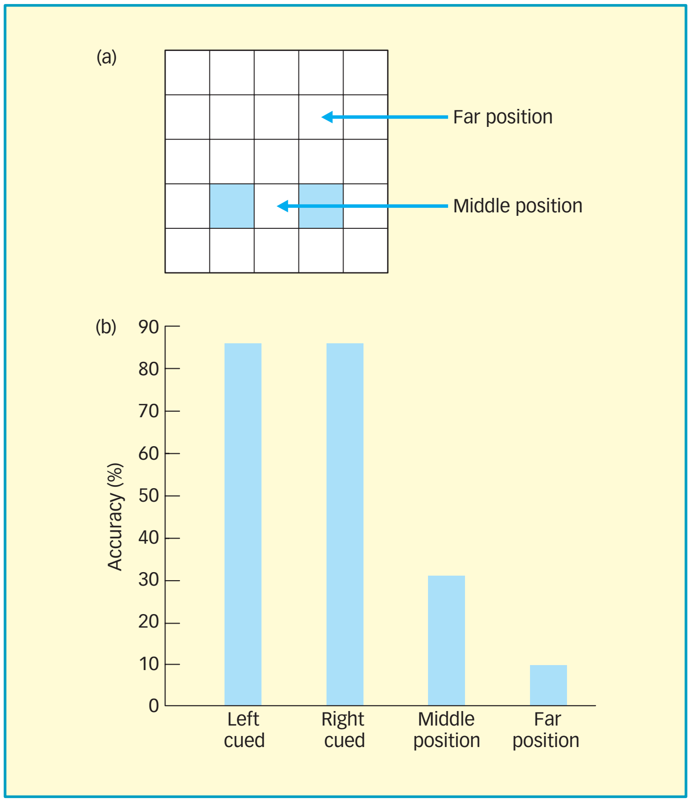
Focused attention is more like a zoom lens than a spotlight. Consider a study by Müller et al. (2003). On each trial, participants were presented with four squares arranged as in the figure on the right. They were then cued



Schematic illustration of the Müller et al. (2003) experimental design. Cues were presented for 4, 7, or 10 seconds and indicated the possible locations of the target (white circle). Either one, two (as in this example), or four locations were cued, determining the size of the attended region. From Müller 2003. Copyright © 2003 Society for Neuroscience. Reproduced with permission.

to focus their attention on one given square, on two given squares, or on all four squares. After that, four objects were presented (one in each square), and participants decided whether a target (blue circle) was among them. When a target was present, it was always in one of the cued squares. For reasons that will become apparent shortly, Müller et al. (2003) made use of brain imaging to obtain information about brain activation in the various conditions.

There were two key findings. First, as predicted by zoom-lens theory, targets were detected fastest when the attended region was small (i.e., only one square) and slowest when it was large (i.e., all four squares). Second, brain imaging revealed that activation in early visual areas was most widespread when the attended region was large and was most limited in scope when the attended region was small. This finding provides support for the notion that the attentional beam can be wide or narrow.



(a) One cue arrangement with the shaded squares being cued. On 80% of trials the targets were presented to the cued squares; on 20% of trials the targets were presented to the middle and far positions. Adapted from Awh and Pashler (2000). (b) Target detection as a function of whether target was cued (left or right) or not (middle and far positions). Data from Awh and Pashler (2000).

Are you convinced by now that visual attention can accurately be described as resembling a spotlight or a zoom lens? If so, you are mistaken! In fact, visual attention is more *flexible* than implied by the analogy with a spotlight or zoom lens. For example, we can exhibit **split attention**, in which we direct attention to two regions of space *not* adjacent to each other. Awh and Pashler (2000) presented participants with a 5 × 5 visual display containing 23 letters and 2 digits. They had to report the identity of the two digits. Just before the display was presented, participants received two cues indicating the probable locations of the two digits. However, these cues were invalid or misleading on 20% of trials. The crucial condition was one in which the cues were invalid, with one of the digits being presented in between the cued locations.

How did participants perform on the digit presented between the two cued locations? According to the spotlight and zoom-lens theories, focal attention should have included the two cued locations and the space in between. In that case, performance should have been high for the digit because it received full attention. In contrast, if split attention is possible, performance should have been poor because only the cued locations would have received full attention. In fact, performance was much lower for digits presented between cued locations than for digits presented to cued locations (see the figure on the left). Thus, split attention is possible and the spotlight/zoom-lens approach is inadequate. The existence of split attention suggests that attention can be shaped like a doughnut in which there is nothing in the middle.

ATTENTION TO LOCATIONS OR TO OBJECTS?

Spotlight and zoom-lens theories of visual attention have proved reasonably successful in spite of their problems in accounting for split attention. Such theories assume that visual attention is directed to a given location or area within the visual field. In fact, however, visual attention can be directed to objects rather than to particular regions. Neisser and Becklen (1975) superimposed two moving scenes on top of each other. Participants found it easy to attend to one scene while ignoring the other, even though the two scenes were in the same location. These findings suggest that objects within the visual environment can be the main focus of attention.

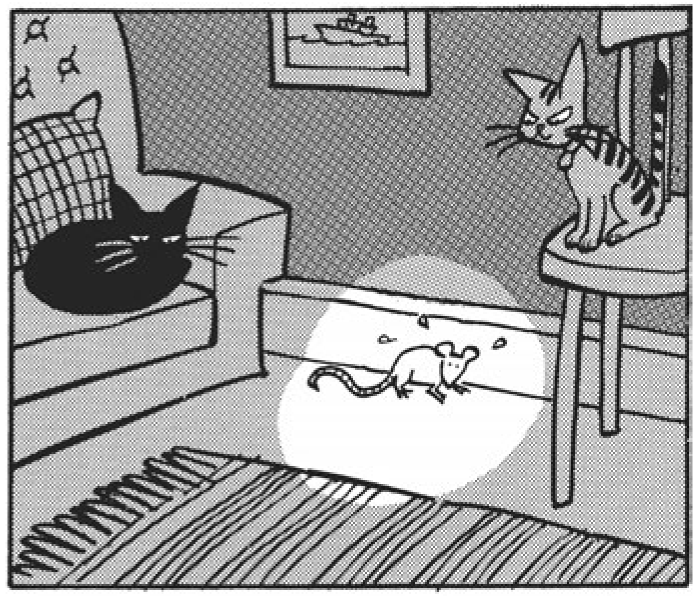
O'Craven, Downing, and Kanwisher (1999) carried out a study resembling that of Neisser and Becklen (1975). They also found that visual attention could be directed to objects rather than to a particular location. Participants were presented with two stimuli (a face and a house) that overlapped transparently at the same location with one of the

Key Term

Split attention: allocation of attention to two nonadjacent regions of visual space.

objects moving slightly. They were told to attend either to the direction of motion of the moving stimulus or to the position of the stationary stimulus. Suppose attention was location-based in this study. In that case, participants would always have attended to both stimuli, because they were both in the same location. In contrast, suppose attention was object-based. In that case, processing of the attended stimulus would have been more thorough than that of the unattended one.

O'Craven et al. (1999) tested the above competing predictions by assessing brain activation in areas selectively involved in processing faces or houses. There was more activity in the face-specific brain area when the face stimulus was attended and more activity in the house-specific brain area when the house stimulus was attended. Thus, visual attention seemed to be object-based rather than location-based in this experiment.



Is attention focused on the object or the location?

WHAT HAPPENS TO UNATTENDED STIMULI?

We turn now to the fate of unattended visual stimuli. Unattended visual stimuli receive less processing than attended ones. Martinez et al. (1999) compared event-related potentials (ERPs) to attended and unattended visual displays. The attended displays produced a greater first positive wave (P1) 70–75 ms after stimulus presentation and a greater first negative wave (N1) 130–140 ms after stimulus presentation. These findings indicate that attended stimuli are processed more thoroughly than unattended ones. However, ERPs 50–55 ms after stimulus presentation showed no difference between attended and unattended displays, so attentional processes don't influence the very early stages of processing.

Further evidence that unattended visual stimuli receive less processing than attended ones was reported by Wojciulik, Kanwisher, and Driver (1998). Participants were presented with displays containing two faces and two houses. They attended to the faces or to the houses with the other type of stimulus being unattended. There was significantly more activity in a part of the brain involved in face processing when the faces needed to be attended to than when they did not. This indicates that the faces received less processing when unattended.

DISORDERS OF ATTENTION

We can discover much about attentional processes by studying brain-damaged patients suffering from various attentional disorders. We will consider two of the main ones: neglect and extinction. **Neglect** (or unilateral neglect) is typically found after brain damage in the right parietal lobe (towards the back of the brain) and is often caused by a stroke. Neglect patients with right-hemisphere damage don't notice (or fail to respond to) objects presented to the left side of the visual field. This occurs because of the nature of the visual system—information from the left side of the visual field proceeds to the right hemisphere of the brain. Driver and Vuilleumier (2001, p. 40) described some of the problems of neglect patients, who "often behave as if half of their world no longer exists. In daily life, they may be oblivious to objects and people on the neglected side of the room, may eat from only one side of their plate . . . and make-up or shave only one side of their face."

Extinction is a phenomenon often found in neglect patients although the two disorders are distinct. The two disorders often co-exist because they involve damage to anatomically close brain areas (Karnath, Himmelbach, & Küker, 2003). In extinction, a *single* stimulus on either side of the visual field can be judged as well as by healthy individuals. However, when *two* stimuli are presented together, the one further toward the neglected side of the visual field tends to go undetected. Some patients only show extinction when the objects presented simultaneously are the same. Extinction is a serious condition because we are typically confronted by multiple stimuli at the same time in everyday life.

Key Terms

Neglect:
a disorder of visual attention in which stimuli (or parts of stimuli) presented to the side opposite the brain damage are not detected; the condition resembles **extinction** but is more severe.

Extinction:
a disorder of visual attention in which a stimulus presented to the side opposite the brain damage is not detected when another stimulus is presented at the same time.

Explaining extinction

Most experts argue that *competition* among stimuli is of crucial importance in understanding extinction. For example, Marzi et al. (2001, p. 1354) argued that, "The presence of extinction only during bilateral [on both sides] stimulation is strongly suggestive of a competitive mechanism, whereby the presence of a more salient [prominent] stimulus presented on the same side of space as that of the brain lesion (ipsilesional side) captures attention and hampers the perception of a less salient stimulus on the opposite (contralesional) side."

Rees et al. (2000) assessed the processing of extinguished stimuli using brain imaging. Extinguished stimuli produced moderate levels of activation in the primary visual cortex and nearby areas. These findings suggest that stimuli of which the patient was unaware were nevertheless processed reasonably thoroughly.

Explaining neglect

Neglect can be understood in part in the context of a theoretical approach put forward by Corbetta and Shulman (2002). According to this approach, there are two major attentional systems. One attentional system is voluntary or goal-directed, whereas the other system is involuntary or stimulus-driven. According to Corbetta and Shulman, the goal-directed or top-down system is involved in the selection of sensory information and responses. It is influenced by expectation, knowledge, and current goals. In contrast, the stimulus-driven or bottom-up system is involved in the detection of salient or conspicuous unattended visual stimuli (e.g., the lights on a speeding ambulance turning on and off). This system has a circuit-breaking function, meaning that visual attention is redirected from its current focus. In practice, these two systems generally influence and interact with each other to determine what is attended.

How can we relate this theory to neglect? Corbetta and Shulman (2002) argued that neglect patients typically have damage to the stimulus-driven attentional system. This is supported by the finding that many neglect patients have damage to the right temporo-parietal junction (Vallar & Perani, 1987), an important part of the stimulus-driven system.

Bartolomeo and Chokron (2002) agreed that neglect is the result of an impaired stimulus-driven system, and argued that the goal-directed system is reasonably intact in neglect patients. It follows that the attentional performance of neglect patients should be much better than usual when they can use the goal-directed or top-down attentional system. Smania et al. (1998) compared the time taken to detect stimuli when the side of the visual field was predictable (thus permitting use of the goal-directed system) and when it was determined at random (thus not permitting use of that system). Neglect patients responded faster in the attended field *and* the unattended (neglect) field when the side to which stimuli would be presented was predictable.

Duncan et al. (1999) presented arrays of letters briefly, and asked neglect patients to recall all the letters or only the ones in a prespecified color. It was assumed that the goal-directed or top-down attentional system could only be used effectively when target letters were identified by color. As expected, recall of letters presented to the left (neglect) side was much worse than of letters presented to the right side when all letters had to be reported. However, neglect patients resembled healthy controls in showing comparable recall of letters presented to each side of the visual field when only letters in a certain color were reported. Thus, neglect patients showed reasonably good top-down attentional control.

How do we distinguish and follow one conversation out of many in situations like this?

AUDITORY ATTENTION

One of the important issues in auditory attention is to explain our ability to follow just one conversation when several people are talking at once. Colin Cherry (1953) referred to this issue as the "cocktail party" problem, and carried out research on it—see the Key Study below.

Key Study

Cherry (1953): The cocktail party problem

Cherry found that we make use of physical differences between the various auditory messages to select the one of interest. These physical differences include differences in the sex of the speaker, in voice intensity, and in the speaker's location. When Cherry presented two messages in the same voice at once (thus removing these physical differences), listeners found it very hard to separate out the two messages purely on the basis of meaning.

Cherry (1953) also carried out studies using the **shadowing task**, in which one auditory message had to be shadowed (repeated back aloud) while a secondary auditory message was presented to the other ear. Very little information seemed to be processed from the secondary or unattended message. Listeners rarely noticed when that message was spoken in a foreign language or in reversed speech. In contrast, physical changes (e.g., the insertion of a pure tone) were usually detected, and listeners noticed the speaker's sex. The conclusion that unattended auditory information receives minimal processing is supported by the finding that there is very little memory for words on the unattended message presented 35 times (Moray, 1959).

Discussion points

1. Are you surprised by any of Cherry's findings?
2. Why do you think that Broadbent found Cherry's findings of great interest?

KEY STUDY EVALUATION

The research by Colin Cherry is a very good example of how a psychologist, noticing a real-life situation, is able to devise a hypothesis and carry out research in order to explain a phenomenon, in this case the "cocktail party" effect. Cherry tested his ideas in a laboratory using a shadowing technique and found that participants were really only able to give information about the physical qualities of the nonattended message (whether the message was read by a male or a female, or if a tone was used instead of speech). Cherry's research could be criticized for having moved the real-life phenomenon into an artificial laboratory setting. However, this work opened avenues for other researchers, beginning with Broadbent, to elaborate theories about focused auditory attention.

Broadbent (1958) discussed findings from the **dichotic listening task**. What usually happens is that three digits are presented one after the other to one ear, while at the same time three different digits are presented to the other ear. After the three pairs of digits have been presented, participants recall them in whatever order they prefer. Recall is typically ear by ear rather than pair by pair. If 496 were presented to one ear and 852 to the other ear, recall would be 496852 rather than 489562.

CLASSIC THEORIES

Broadbent (1958) proposed the first detailed theory of auditory attention. The key assumptions in his filter theory were as follows (see the figure on the following page):

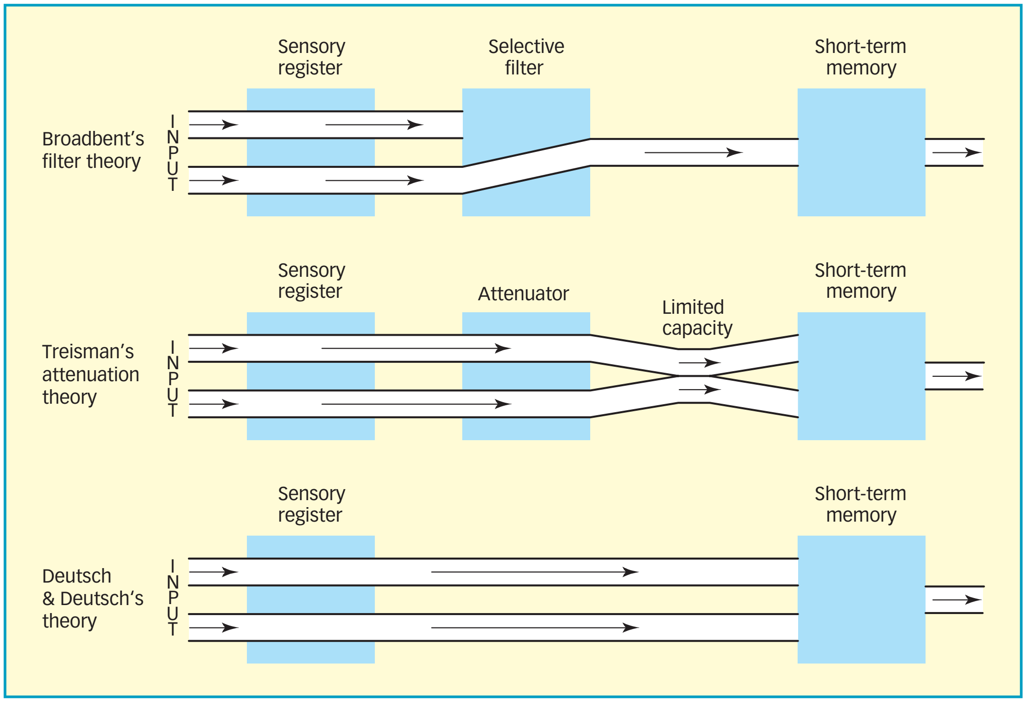
- Two stimuli or messages presented at the same time gain access in parallel (at the same time) to a **sensory buffer**, which contains information briefly before it is attended to or disappears from the processing system.

Key Terms

Shadowing task: a task in which there are two auditory messages, one of which has to be repeated back aloud or shadowed.

Dichotic listening task: a task in which pairs of items are presented one to each ear, followed by recall of all items.

Sensory buffer: a mechanism that maintains information for a short period of time before it is processed.



- One input is then allowed through a filter on the basis of its physical characteristics, with the other input remaining in the buffer.
- It takes approximately 500 ms to switch attention, and so there is rarely time to switch attention to information in the sensory buffer before it is lost.
- The filter prevents overloading of the limited-capacity mechanism beyond the filter; this mechanism processes the input thoroughly.
- There is no identification or recognition of an object (involving processing of its meaning) without attention.

This theory handles Cherry's basic findings, with unattended messages being rejected by the filter and thus receiving very little processing. It also accounts for performance on Broadbent's original dichotic listening task. This is based on the assumption that the filter selects one input on the basis of the most obvious physical characteristic distinguishing the two inputs (i.e., the ear of arrival).

Treisman (1964) proposed a modified version of Broadbent's filter theory. In her attenuation theory, the processing of unattended stimuli is only attenuated or reduced. In Broadbent's theory, it was proposed that there is a bottleneck early in processing. In Treisman's theory, the location of the bottleneck is more flexible (see the figure above). It is as if people possess a "leaky" filter, making selective attention less efficient than assumed by Broadbent (1958).

According to Treisman (1964), stimulus processing proceeds systematically, starting with analyses based on physical cues, and then moving on to analyses based on meaning. If there is insufficient processing capacity to allow full stimulus analysis, then some later analyses are omitted with "unattended" stimuli. This theory neatly predicts Cherry's (1953) finding that physical characteristics of unattended inputs (e.g., sex of the speaker) are noticed rather than their meaning.

The third and final of the classic theories was put forward by Deutsch and Deutsch (1963). They claimed that all stimuli are analyzed fully, with the most important or relevant stimulus determining the response. This theory differs from filter and attenuation theories in placing the bottleneck closer to the response end of the processing system (see the figure above). Deutsch and Deutsch's assumption that all stimuli are analyzed completely, but that most of the analyzed information is lost almost immediately, seems implausible.

In sum, all three theories explain why it is that we attend (and respond) to just one auditory input when two or more such inputs are presented at the same time. The key difference among the theories is in terms of the predicted amount of processing of unattended stimuli:

1. Processing is typically limited to physical features (Broadbent).
2. Processing is flexible and sometimes includes semantic features (Treisman).
3. Processing of unattended stimuli is thorough (Deutch & Deutsch).

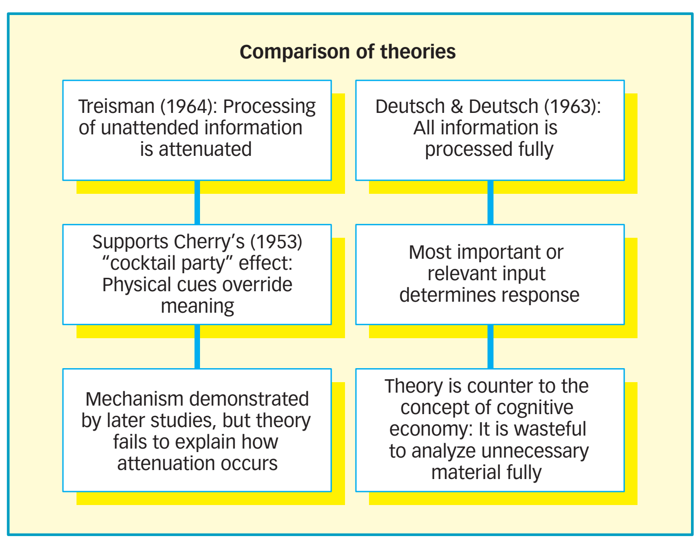
Below we consider these theories in the light of the evidence. Before we do so, there is one final point that needs to be made. All three theories were initially applied only to studies on auditory attention. However, processing bottlenecks can occur in visual attention as well as auditory attention, and so the theories are also of relevance to studies on visual attention.

Findings

Deutsch and Deutsch's (1963) theory has proved the least successful of the classic theories. Treisman and Riley (1969) asked participants to shadow one of two auditory messages presented at the same time. Whenever they detected a target word in either message, they were to stop shadowing and tap. According to Deutsch and Deutsch, there is complete processing of all stimuli, and so it would be expected that there would be no difference in detection rates between the two messages. In fact, many more target words were detected on the shadowed message than on the nonshadowed one, presumably because listeners were attending to the shadowed message.

Neurophysiological studies provide substantial evidence against Deutsch and Deutsch's theory (see Lachter, Forster, & Ruthruff, 2004, for a review). For example, Coch, Sanders, and Neville (2005) used a dichotic listening task in which participants attended to one of two auditory messages. Their task was to detect probe targets presented on the attended or the unattended message. Event-related potentials (ERPs) were recorded. ERPs about 100 ms after probe presentation were greater when the probe was presented on the attended message than on the unattended one, suggesting that there was more processing of attended than of unattended probes. This is inconsistent with Deutsch and Deutsch's assumption that *all* inputs are processed thoroughly.

The battleground between Broadbent's filter theory and Treisman's attenuation theory has focused mainly on the fate of unattended stimuli. Treisman's theory allows for more processing (including semantic processing) of unattended stimuli than does Broadbent's theory. There is much evidence that apparently unattended stimuli are sometimes processed fairly thoroughly, thus supporting Treisman's approach. Underwood (1974) asked listeners to detect digits presented on the shadowed (attended) or nonshadowed (unattended) message. Those who had not done the task before detected only 8% of the digits on the nonshadowed message. In contrast, an experienced researcher in the area detected 67% of the nonshadowed digits. Von Wright, Anderson, and Stenman (1975) gave listeners two auditorily presented lists of words, telling them to shadow one list and ignore the other. When a word previously associated with electric shock was presented on the non-attended list, there was sometimes a physiological response (galvanic skin response). There was the same effect when a word very similar in sound or meaning to the shocked word was presented. Thus, sound and meaning information on the unattended message was sometimes processed. Since physiological responses were observed on only relatively few trials, thorough processing of unattended information occurred only some of the time.



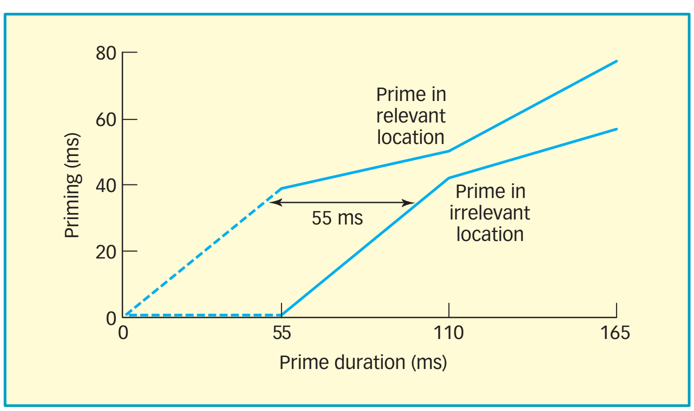
Conway, Cowan, and Bunting (2001) found that many listeners detected their own name when it was presented on the unattended auditory input. This finding suggests that important unattended semantic information can get through the "leaky" filter.

There is a simple way of modifying Broadbent's theory to account for the above findings. Remember that Broadbent argued that there is a sensory buffer or immediate memory that briefly holds information in a relatively unprocessed state. We now know that there are separate sensory buffers for the auditory modality (echoic memory: Neisser, 1967) and the visual modality (iconic memory: Sperling, 1960). If we could switch our attention rapidly to the information in the appropriate sensory buffer, we would be able to process "unattended" stimuli thoroughly. Broadbent (1958) was pessimistic about the possibility of doing that because he argued that it takes 500 ms (half a second) to shift attention. In fact, as Lachter et al. (2004) pointed out, Broadbent greatly exaggerated the time needed, since involuntary shifts of attention can occur in as little as 50 ms (Tsal, 1983). The crucial point is that shifting attention to information in a sensory buffer can be almost as effective as shifting attention to the actual object. You may have had the experience of being asked a question while doing something else, and immediately replying, "What did you say?" Before you have finished your sentence, you realize that you do know what the person said. This "playback" facility depends on echoic memory.

We now have *two* contrasting explanations for the occasional semantic processing of "unattended" stimuli. According to Treisman, this depends on a leaky filter. According to Broadbent's modified theory, it depends on what Lachter et al. (2004) called "slippage," meaning that attention is shifted to allegedly "unattended" stimuli, and so they aren't really unattended at all. Close inspection of the evidence suggests that slippage may well be more important than leakage. For example, remember that Von Wright et al. (1975) found heightened physiological responses (galvanic skin responses) to shock-associated words presented on the "unattended" message. Dawson and Schell (1983) replicated that finding. However, they then identified trials on which there was evidence that listeners had shifted attention to the "unattended" message (e.g., failures of shadowing on the "attended" message). Most of the enhanced physiological responses occurred on trials on which it seemed likely that listeners had shifted attention.

As discussed above, Conway et al. (2001) found that listeners sometimes detected their own name presented on the "unattended" input. However, when they divided listeners into those with low and high memory span, it was predominantly those with low memory span who showed this effect. Since individuals with low memory span are more distractible than those with high memory span (Barrett, Tugade, & Engle, 2004), they would have been more likely than those with high memory span to attend to stimuli on the "unattended" channel.

Lachter et al. (2004) argued that what was needed was to devise a situation in which slippage was almost impossible. This can be done by not giving participants sufficient time to switch attention to "unattended" information in a sensory buffer. They used a lexical-decision task in which participants decided whether a string of letters formed a word. This letter string was immediately preceded by a prime word either the same as or unrelated to the target word presented for lexical decision. This prime word was presented for 55 ms, 110 ms, or 165 ms, and was attended or unattended. The extent of any priming effect was assessed by seeing how much faster the lexical decision was when the prime word was the same as the target word rather than being unrelated.



Priming in ms as a function of prime duration and whether the prime was presented to the attended (relevant) location or the unattended (irrelevant) location.

What predictions can we make? According to the modified version of Broadbent's theory, participants would need to shift attention to the "unattended" prime to show a priming effect. Since attentional shifting takes at least 50 ms, there should be no priming effect when the prime word in the unattended location was presented for 55 ms. However, a priming effect should be detectable when it was presented for 110 ms or 165 ms. That is precisely what happened (see the figure on the left). There was no evidence that the "unattended" prime word was processed when stringent steps were taken to eliminate slippage but not to prevent leakage. This suggests that slippage is needed if unattended stimuli are to be processed.

Evaluation

+ Broadbent's filter theory is of great historical importance. It was the first theory incorporating the notion of an information-processing system with several interrelated processes.
+ Treisman's attenuation theory is more flexible than filter theory. The notion of a "leaky" filter accurately predicts that there will sometimes be fairly thorough processing of unattended stimuli.
+ A modified version of Broadbent's theory in which it is assumed that attention can be shifted rapidly can account for most of the findings. This modified theory explains the findings of Lachter et al. (2004).
− Detailed consideration of the evidence suggests that thorough processing of unattended stimuli may depend less on leakage than was assumed by Treisman.
− Deutsch and Deutsch's late-selection theory seems implausible and has attracted little clear support.
− As Styles (1997, p. 28) pointed out, "Finding out *where* selection takes place may not help us to understand *why* or *how* this happens."

MULTITASKING

Most people find that their lives are becoming busier and busier as time goes by. Indeed, life is so busy that we often try to do two things at the same time. For example, we may buy bus or train tickets while holding a conversation on a mobile phone or we access our emails while chatting with someone. The term **multitasking** refers to the performance of more than one task at a time, and our focus in this section is on the effectiveness (or otherwise!) of our attempts to multitask.

Skilled touch typists can hold a conversation and attend to other stimuli with very little effect on their typing speed or accuracy.

The fact that most of us often engage in multitasking suggests we believe ourselves capable of performing two tasks successfully at the same time. Indeed, the main reason we multitask is because we think it will save us precious time compared to the traditional approach of doing one thing at a time. If that isn't the case, then we are simply wasting our time and incurring higher stress levels!

It is commonly believed that women are better than men at multitasking, perhaps because women spend more of their time than men trying to do two things at once. There are surprisingly few studies in which the multitasking abilities of men and women have been compared directly. However, Rubinstein, Meyer, and Evans (2001) found no evidence of any gender differences in multitasking performance in several experiments.

It is also commonly believed that less intelligent people are worse at multitasking than more intelligent ones. This notion was given vivid expression by American President Lyndon Johnson. He claimed that Gerald Ford (a slow-witted Congressman who later became President) "can't fart and chew gum at the same time." We don't know whether this claim was true, but intelligence *is* related to the ability to perform two tasks together. For example, Engle, Tuholski, Laughlin, and Conway (1999) asked participants to

Key Term

Multitasking: performing two or more tasks at the same time by switching rapidly between them.

perform either one or two tasks at the same time. Intelligence was a good predictor of dual-task performance but was unrelated to single-task performance.

THINKING AND DRIVING

When we consider multitasking in everyday life, an issue of considerable practical importance is whether the ability to drive a car is impaired when the driver uses a mobile phone. There has been much controversy on this issue. More than a dozen countries (including the UK) have passed laws restricting the use of mobile phones while driving, but millions of irate motorists complain that such legislation infringes civil liberties. We turn to a consideration of the evidence.

Redelmeier and Tibshirani (1997) studied the mobile-phone records of 699 drivers who had been involved in a car accident. One quarter of them had used their mobile phone within the 10-minute period preceding the accident, and the figure was similar for those using handheld and hands-free phones. They concluded that use of a mobile phone produced a four-fold increase in the likelihood of having a car accident.

David Strayer and William Johnston (2001) carried out an experiment in which participants braked as rapidly as possible when they detected a red light. This task was carried out on its own or at the same time as the participants held a conversation using a handheld or hands-free mobile phone. Participants missed significantly more red lights when using a mobile phone (7% vs. 3%, respectively), with performance being very similar in the handheld and hands-free conditions. In addition, the time taken to respond to the red light was about 50 ms longer in the mobile phone conditions. That may sound trivial. However, consider a motorist driving at 70 mph (110 kph). The additional 50 ms taken to brake would mean that the motorist's car would travel an extra 5 feet (1.5 meters) before stopping. That might mean the difference between stopping just behind the car in front or smashing into the back of it.

Switch off your mobile!

Believe it or not, some students feel that cognitive psychology has little relevance to everyday life. However, research on divided attention is of direct relevance to a practical issue that has been much debated in recent years, namely whether motorists should be allowed to use mobile phones while driving. As someone who has nearly been hit by two mobile-using motorists who were driving on the wrong side of the road, I have my own personal views on the matter. What about the scientific evidence? Strayer and Johnston (2001) found that the chances of missing a red light more than doubled when the participants were engaged in conversation on a handheld mobile phone, and the effects were almost as great when using a hands-free mobile phone. In addition, using a mobile phone greatly reduced the speed of responding to those traffic signals that were detected. These various adverse effects were greater when the participants were talking than when they were listening, but both effects were significant.

The above findings led Strayer and Johnston (2001, p. 462) to conclude that, "[Mobile]-phone use disrupts performance by diverting attention to an engaging cognitive context other than the one immediately associated with driving." That conclusion strongly suggests that the use of mobile phones while driving should be restricted or banned, as is already the case in more than a dozen countries.

Strayer, Drews, and Johnston (2003) explored in more detail the negative effects of using a mobile phone. They found that drivers using a handheld mobile phone missed or had poor recall of billboard signs along the route. The eye movements of these drivers showed that they often did not look at such signs, even when the information was presented in the center of the visual field. Thus, use of mobile phones leads drivers to withdraw at least some of their attention from the visual scene in front of them.

DOES PRACTICE MAKE PERFECT?

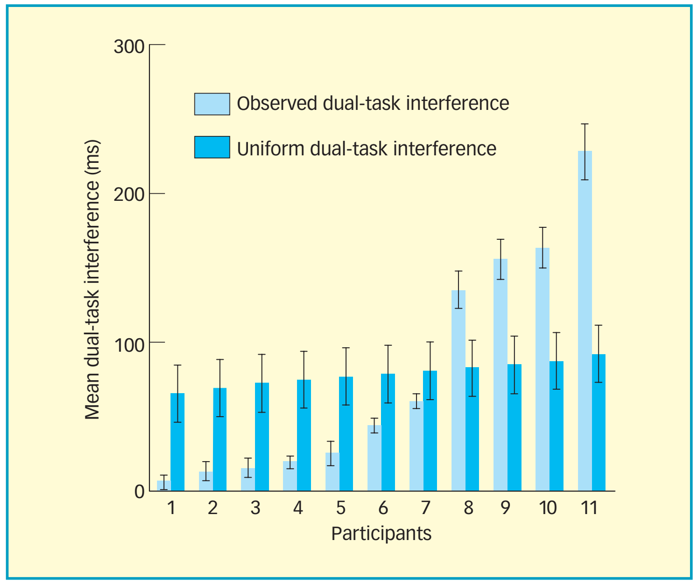
The findings discussed above suggest that the Roman sage Publilius Syrus may have been correct when he said that, "To do two things at once is to do neither." However, common sense suggests that multitasking is most successful when the two tasks being performed together are well-practiced and so involve relatively automatic skills. In other words, "Practice makes perfect." For example, skilled drivers can drive while listening to the radio, air-traffic controllers can monitor the positions of numerous air-planes at the same time, and a one-man band can play several instruments at once.

Evidence supporting commonsensical views on the value of practice was reported by Spelke, Hirst, and Neisser (1976). Two students (Diane and John) received 5 hours training a week for 3 months on various tasks. Their first task was to read short stories for comprehension while writing down words to dictation. Initially they found it very hard to combine these tasks, with their reading speed and handwriting both suffering considerably. After 6 weeks of training, however, Diane and John could read as rapidly and with as much comprehension when taking dictation as when only reading, and the quality of their handwriting had also improved.

Spelke et al. (1976) were still not satisfied with the students' performance. For example, Diane and John could recall only 35 out of the thousands of words they had written down at dictation. Even when 20 successive dictated words formed a sentence or came from the same category (e.g., four-footed animals), the students were unaware of that. With further training, however, they could write down the names of the categories to which the dictated words belonged while maintaining normal reading speed and comprehension.

In spite of findings such as those of Spelke et al. (1976), several experts (e.g., Pashler, Johnston, & Ruthruff, 2001) argue that we will always find evidence of interference or disruption in dual-task performance if we use sufficiently sensitive techniques. One such technique involves presenting people with two stimuli (e.g., two lights) each of which is associated with a different response (e.g., pressing different buttons). Their task is to respond to each stimulus as rapidly as possible. When the second stimulus is presented very shortly after the first, there is typically a marked slowing of the response to the second stimulus. This interference effect is known as the **psychological refractory period (PRP) effect**, and it has been obtained in numerous studies (see Pashler et al., 2001, for a review). This effect does *not* occur simply because people aren't used to responding to two immediately successive stimuli. Pashler (1993) discussed one of his studies in which the PRP effect was still observable after more than 10,000 practice trials.

Schumacher et al. (2001) challenged the notion that a PRP effect will always be found. They used two tasks: (1) say "one," "two," "three" to low-, medium-, and high-pitched tones; (2) respond with different fingers to four stimuli (0 - - -; - 0 - -; - - 0 -; and - - - 0) having a disk (0) in different locations. These two tasks were performed on over 2000 trials, at the end of which 5 of the 11 participants performed them virtually as well together as singly (see the figure on the right). In contrast, four participants had high levels of dual-task interference (150 ms or more) even after extensive practice (see the figure on the right). According to Schumacher et al. (2001, p. 107), "Participants may use a variety of task-scheduling strategies (e.g., a cautious one with minimal temporal overlap in processing for the two tasks, or a daring strategy with a great deal of processing overlap) during the course of practice, and so exhibit various amounts of dual-task interference."



Observed (light bars) and expected uniform (dark bars) amounts of dual-task interference in ms at the end of practice rank-ordered from smallest to largest for 11 participants. From Schumacher et al. (2001). Copyright © 2001 Blackwell Publishing. Reprinted with permission.

In sum, two tasks can rarely be performed at the same time with no disruption or interference. When dual-task performance is very successful (e.g., Schumacher et al., 2001; Spelke et al., 1976), this is nearly always as a result of using easy tasks and extensive practice. We turn now to a consideration of *how* practice has this beneficial effect.

PRACTICE AND AUTOMATICITY

It has often been argued (e.g., Shiffrin & Schneider, 1977) that practice leads to improved dual-task performance because it allows some processing activities to become automatic and so not reliant on attention. Here are some of the main criteria for automatic processes:

- They are fast
- They don't require attention, and so don't reduce the capacity to perform other tasks at the same time
- They are unavailable to consciousness
- They are unavoidable, meaning they always occur when an appropriate stimulus is presented.

Key Terms

Psychological refractory period (PRP) effect: the slowing of response to the second of two stimuli when presented close together in time.

Key Study

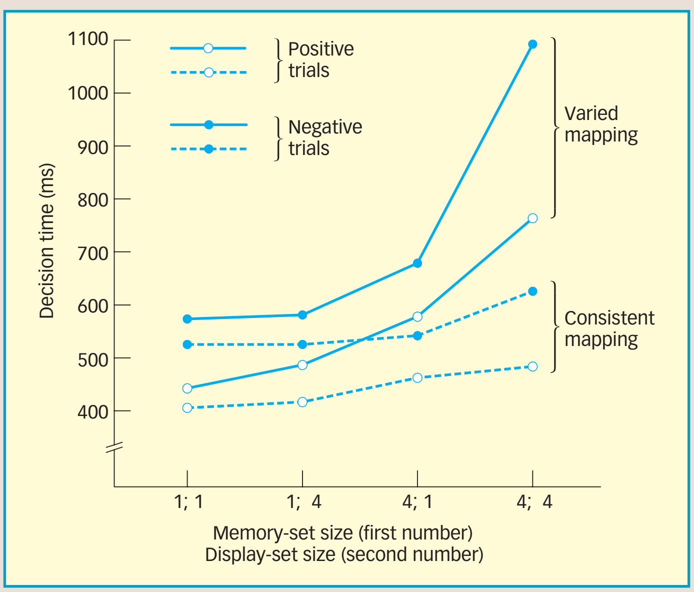
Schneider and Shiffrin: Automatic processing

Classic studies on automatic processing were reported by Shiffrin and Schneider (1977) and Schneider and Shiffrin (1977). They used a task in which participants memorized up to four letters (the memory set) and were then shown a visual display containing up to four letters. Their task was to decide rapidly whether one of the letters in the visual display was the same as any of the letters in the memory set. The crucial manipulation was the type of mapping used:

1. *Consistent mapping*: Only consonants were used as members of the memory set, and only numbers were used as distractors in the visual display (or vice versa).
2. *Varied mapping*: A mixture of numbers and consonants formed the memory set and provided distractors in the visual display.

What do you think happened in terms of performance speed? You probably guessed that consistent mapping led to faster performance than varied mapping, but the actual difference may be greater than you thought (see the figure below). The numbers of items in the memory set and in the visual display greatly affected decision speed in the varied mapping conditions but not in the consistent mapping conditions. According to Shiffrin and Schneider (1977), participants performed well with consistent mapping because they used automatic processes operating at the same time. These automatic processes have developed as a result of many years of practice in distinguishing between letters and numbers. In contrast, performance with varied mapping required controlled processes, which are of limited capacity and require attention. As a result, participants had to compare each item in the memory set with each item in the visual display one at a time until a match was found or every comparison had been made.

You may be thinking that automatic processes are more useful than controlled ones. However, automatic processes suffer from the serious limitation that they are rigid and inflexible. As a result, performance based on automatic processes suffers when there is a change in what is required. Shiffrin and Schneider (1977) showed this in an experiment on consistent mapping when the consonants B to L formed one set and the consonants Q to Z formed the other set. As before, items from only one set were always used in the formation of the memory set and the distractors in the visual



Response times on a decision task as a function of memory-set size, display-set size, and consistent versus varied mapping. Data from Shiffrin and Schneider (1977).

display were all selected from the other set. The initial 2100 trials with one consistent mapping were followed by a further 2100 trials with the reverse consistent mapping. Thus, the items in the memory set were now always drawn from the consonants Q to Z if they had previously been drawn from the set B to L. This reversal of the mapping conditions greatly disrupted performance—it took nearly 1000 trials before performance recovered to its level at the very start of the experiment!

What conclusions can we draw from the above findings? "Automatic processes function rapidly and in parallel but suffer from inflexibility; controlled processes are flexible and versatile but operate relatively slowly and in a serial fashion" (Eysenck, 1982, p. 22). Thus, automatic and controlled processes both possess advantages and disadvantages.

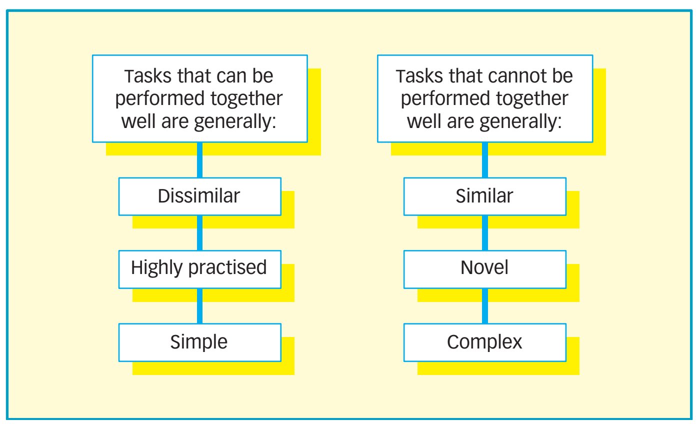
Discussion points

1. How useful is this research by Shiffrin and Schneider (see next for some pointers)?
2. Think of some examples of automatic and controlled processes in your everyday life.

KEY STUDY EVALUATION

Schneider and Shiffrin's work on controlled and automatic processing is another good example of a theory being tested and supported by the use of experiments. Interestingly, some advertising has made use of similar combinations of letters and numbers to good effect, for example the film *SE7EN* (Seven), which demonstrates how difficult it can be to override the automatic process of reading. The research by Schneider and Shiffrin supplies confirmation of what may seem obvious, that some processes become automatic with time, but it does not specify how or what is actually occurring.

SIMILARITY



As a general rule of thumb, tasks that are similar to each other are more difficult to perform reasonably well together than dissimilar ones. For example, you can probably study while listening to music, but might find it very difficult to rub your stomach with one hand while patting your head with the other.

There are various ways in which two tasks can be similar. First, they can be similar in terms of stimulus modality (e.g., both involving visual or auditory presentation). Treisman and Davies (1973) found that two monitoring tasks interfered with each other much more when the stimuli on both tasks were in the same modality (visual or auditory) than when they were in different modalities. Second, they can be similar in terms of central processing (e.g., both involving spatial processing). Third, tasks can be similar in terms of responses (e.g., both requiring manual responses). Think back to the study by Schumacher et al. (2001) in which they found that two tasks could be performed at the same time without interference. The two tasks differed in stimulus modality (visual vs. auditory) and in type of response (manual vs. vocal).

Direct evidence that response similarity is important was reported by Van Selst, Ruthruff, and Johnston (1999). They initially used two tasks, one of which required a vocal response and the other a manual response. After extended practice, the interference or PRP effect in responding to the second stimulus was only 50 ms. However, the interference effect was much larger when the experiment was repeated with both tasks requiring manual responses.

It is often hard to decide just how similar or dissimilar two tasks are. For example, how similar are piano playing and poetry writing or driving a car and listening to the radio?

TASK DIFFICULTY

Our ability to perform two tasks at the same time depends on their difficulty level. For example, Sullivan (1976) asked participants to repeat back (shadow) an auditory message and to detect words on a nonshadowed message at the same time. The key manipulation involved varying the complexity of the shadowed message. When the shadowing task was difficult, fewer targets were detected on the nonshadowed message than when the shadowing task was easy.

Greenwald (2003) argued that the easiest tasks are those in which there is a very direct and obvious relationship between stimulus and response. Saying "A" or "B" in response to hearing those letter names is an example of such a task. Another example is moving a joystick switch to the left to an arrow pointing left and moving it to the right to an arrow pointing right. Participants performed these two tasks as well together as on their own.

THEORETICAL PERSPECTIVES

Many theories have been put forward to account for how well (or poorly) we manage to perform two tasks at the same time. Here we consider two of the main theoretical approaches: central capacity theories and multiple-resource theories.

Central capacity theories

We can account for many dual-task findings by assuming there is some central capacity having limited capacity (perhaps resembling the central executive component of working memory—see Chapter 8). The extent to which two tasks can be performed together depends on the demands each task makes on those resources. If the combined demands of the two tasks don't exceed the total resources of the central capacity, then the two tasks won't interfere with each other. However, if the resources are insufficient, then performance disruption will occur.

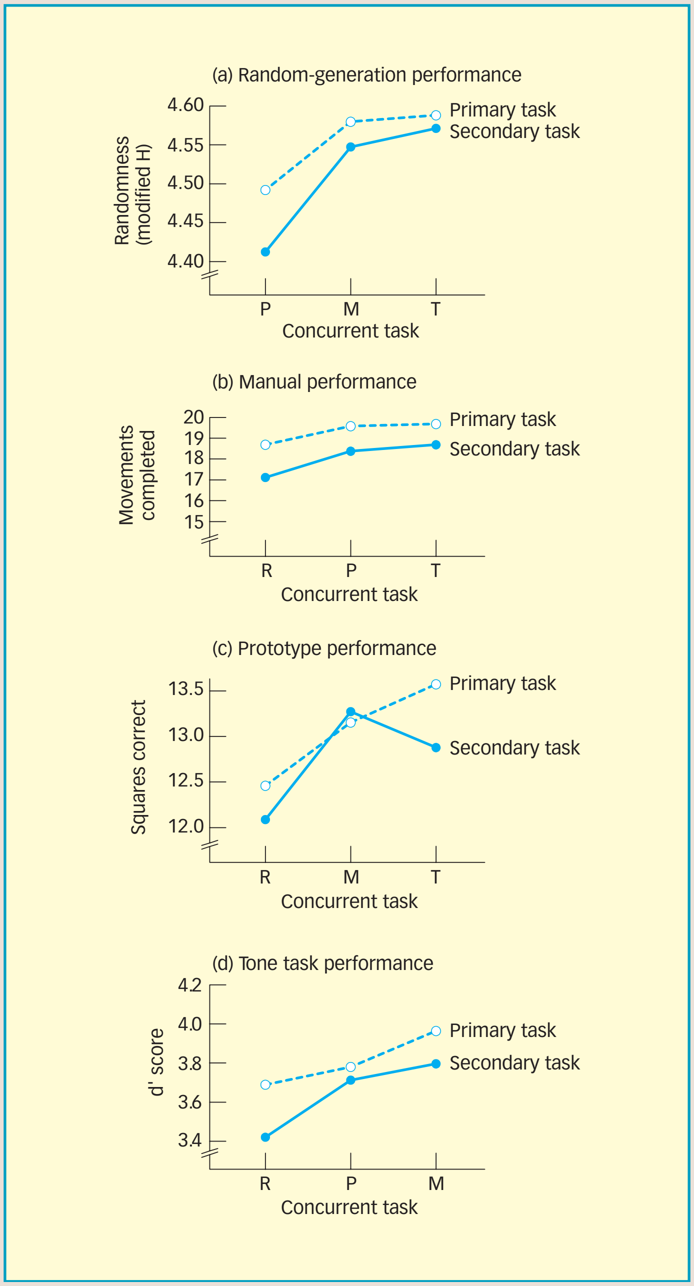
Key Study

Bourke et al. (1996): Support for central capacity

Predictions of central capacity theory were tested by Bourke, Duncan, and Nimmo-Smith (1996) using four different tasks. These tasks were performed in all possible pairings with one task being identified as more important than the other. According to the theory, the task making most demands on the central capacity should interfere most with all three of the other tasks. In contrast, the task making fewest demands on central capacity should interfere least with all the other tasks. Here are the four tasks in order from most to least demanding:

1. *Random generation*: Generating letters at random.
2. *Prototype learning*: Working out the features of two patterns or prototypes from seeing various examples.
3. *Manual task*: Screwing a nut down to the bottom of a bolt and back up to the top, and then down to the bottom of a second bolt and back up, and so on.
4. *Tone task*: Detecting the occurrence of a target tone.

What did Bourke et al. (1996) find? The main findings were as predicted (see the figure on the following page). The most demanding task (random generation) consistently interfered most with the prototype, manual, and tone tasks, and did so whether it was the primary or secondary task. The least demanding task (tone task) consistently interfered least with each of the other three tasks.



Performance on random generation (R), prototype learning (P), manual (M), and tone (T) tasks as a function of concurrent task. Adapted from Bourke et al. (1996).

Discussion points

1. Is it surprising that these very different tasks interfered with each other?
2. Why do you think that the random generation task interfered the most with other tasks, whereas the tone task interfered the least?

KEY STUDY EVALUATION

As we have seen, the four tasks used by Bourke et al. are very different from each other. If performance depended only on very specific processes, then there would presumably have been little or no interference between tasks. The fact that there was considerable interference is strong evidence for a general central processing capacity. It may have occurred to you that participants with special expertise might have found it easier to combine some of the tasks; for example, a mechanic might be very good at handling nuts and bolts. However, the participants were recent university students, and lacked special expertise for any of the tasks.

Just et al. (2001) also obtained support for central capacity theories. They used two tasks performed together or on their own. One task was auditory sentence comprehension (e.g., deciding whether "The pyramids were burial places and they are one of the seven wonders of the ancient world" was true or false). The other task involved mentally rotating three-dimensional figures to decide whether they were the same. These tasks were selected so they would involve very different processes in different parts of the brain.

What did Just et al. (2001) find? First, performance of both tasks was significantly impaired under dual-task conditions compared to single-task conditions. Second, the two tasks mainly activated different parts of the brain (the temporal lobe for the language task and the parietal lobe for the mental rotation task). Third, and most importantly, Just et al. compared the amount of activation associated with each task under single- and dual-task conditions. Brain activation in regions associated with the language task decreased by 53% under dual-task conditions compared to single-task conditions. In similar fashion, brain activation in regions involved in the mental rotation task decreased by 29% under dual-task conditions. The need to distribute a limited central capacity (probably attention) across two tasks meant the amount each task could receive was reduced compared to the single-task condition.

Central capacity theories possess various limitations. First, dual-task performance doesn't *only* depend on some central capacity. The finding that dual-task performance is worse when both tasks involve the same type of response than when they don't (e.g., van Selst et al., 1999) is not directly a result of limitations with some central capacity.

Second, it is possible to "explain" dual-task interference by arguing that the resources of some central capacity have been exceeded, and the absence of interference by assuming the two tasks didn't exceed those resources. However, unless we can measure central processing capacity, we may simply be re-describing the findings rather than providing a proper explanation. In that connection, the use of brain-imaging data to clarify the involvement of attentional processes in single- and dual-task conditions is an important step forward.

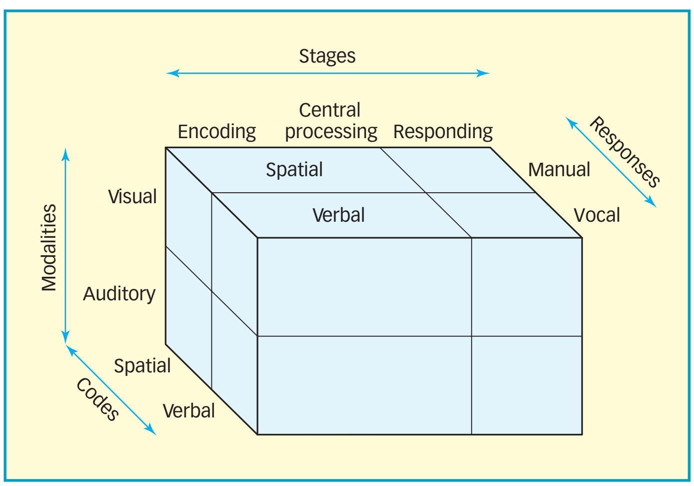
Third, it is very hard to assess the total demands on central capacity imposed by performing two tasks at the same time. Each task imposes its own demands. However, there are also additional demands from coordinating processing on two tasks at the same time, preventing interference between competing responses, and so on.

Multiple-resource model

Wickens (e.g., 1984) argued that the processing system consists of independent processing mechanisms in the form of multiple resources each having limited capacity. If so, then it is clear why the degree of similarity between two tasks is so important: similar tasks compete for the same specific limited resources, and thus produce interference. In contrast, dissimilar tasks involve different resources, and so don't interfere with each other.

Wickens (1984) proposed a three-dimensional structure of human processing resources (see the figure on the left). According to his model, there are three successive stages of processing (encoding, central processing, and responding). Encoding involves the perceptual processing of stimuli, and typically makes use of the visual or auditory modality. Encoding and central processing can involve spatial or verbal codes. Finally, responding involves manual or vocal responses. There are two key assumptions in this model:

1. There are several pools of resources based on the distinctions among stages of processing, modalities, codes, and responses.
2. If two tasks make use of different pools of resources, then people should be able to perform both tasks without disruption.



A proposed three-dimensional structure of human processing resources. From Wickens (1984). Copyright © 1984 Elsevier. Reproduced with permission.

There is much support for this multiple-resource model and its prediction that several kinds of task similarity influence dual-task performance. For example, there is more interference when two tasks share the same modality (e.g., Treisman & Davies, 1973) or when they share the same type of response (e.g., van Selst et al., 1999). However, the model has some limitations. First, it focuses only on visual and auditory inputs or stimuli, but tasks can be presented in other modalities (e.g., touch). Second, there is often some disruption to performance even when two tasks make use of the same modality (e.g., Treisman & Davies, 1973). Third, the model assumes that several tasks could be performed together without interference provided each task used different pools of resources. However, Just et al. (2001) found that two very different tasks (auditory sentence comprehension and mental rotation) couldn't be performed together without interference. Their brain-imaging data suggested there was a limitation on the capacity of some general capacity available for processing, but such a capacity is not included in Wickens' model. Wickens' model can be compared to leaving the Prince of Denmark out of the play *Hamlet*.

Chapter Summary

Object recognition

- The Gestaltists identified several laws of perceptual organization including the law of proximity, the law of similarity, the law of good continuation, and the law of closure. These laws are descriptive rather than explanatory.
- According to viewpoint-dependent theories, object recognition is easier when objects are seen from familiar angles. According to viewpoint-invariant theories, objects are equally well recognized from all angles. Object recognition is much more likely to be viewpoint-invariant when the task is very easy than when it is complex.
- Riddoch and Humphreys (2001) put forward a five-stage model of object recognition, with successive stages concerned with edge grouping, feature binding, view normalization, structural description, and the semantic system.
- Brain-damaged patients have been found with problems of object recognition at each of the five stages identified by Riddoch and Humphreys, thus providing support for their theory. However, they de-emphasize interactions among the different stages.

Visual illusions: Two systems

- Visual perception is typically very accurate, but most people are deceived by a large number of visual illusions.
- According to Milner and Goodale, we have two visual systems. The vision-for-perception system is used for object recognition and is based on a ventral pathway. The vision-for-action system is used for visually guided action and is based on a dorsal pathway.
- There is evidence that the vision-for-perception system is more affected by visual illusions than is the vision-for-action system.
- Patients with optic ataxia have problems mainly with the vision-for-action system, whereas those with visual agnosia have problems centered on the vision-for-perception system.
- The vision-for-action system consists of planning and control systems, only the latter of which is unaffected by visual illusions.

Unconscious perception

- We can assess conscious awareness of visual stimuli by using a relatively lenient subjective threshold or a more stringent objective threshold.
- Several studies on healthy individuals have produced evidence of subliminal perception even when the objective threshold is used. In addition, there is evidence that the effects of subliminal perception can differ substantially from those of conscious perception.

- Brain-damaged patients with blindsight show various perceptual abilities in parts of the visual field for which they report no conscious perceptual experience. For example, they nearly all show some ability to detect light and motion, and some can discriminate shape, direction or movement, and object orientation.
- It is difficult to be certain that any given individual totally lacks conscious experience of a visual stimulus. For example, some blindsight patients describe a "contentless kind of awareness."

Change blindness

- Most people believe that they perceive and remember most of the information in visual scenes. However, this belief is mistaken, as is revealed by the phenomena of change blindness and inattentional blindness.
- Change blindness and inattentional blindness occur most often when observers are not warned of possible changes to the visual environment, when an unexpected object is similar to other objects, and when the object that is changed has not been attended to prior to the change occurring.
- We form fairly detailed visual representations of objects that are the focus of attention. These representations are fitted into a mental map providing a spatial layout of the overall visual scene, which is stored in long-term memory. We tend to assume that the information in long-term memory is more detailed than is actually the case.

Visual attention

- Much of the evidence indicates that visual attention is more like a zoom lens than a spotlight. However, the existence of split attention means that visual attention is not always directed to a given region in visual space.
- Visual attention is flexible. It can be directed either to a given location or to a given object.
- Unattended visual stimuli are generally processed to a moderate extent but less than attended ones.
- Extinction occurs because of competition among stimuli. Neglect patients have a reasonably intact goal-directed system but a severely impaired stimulus-driven system. They show a reasonable ability to detect stimuli in the neglected field when they can use the goal-directed system to predict where target stimuli are likely to be presented.

Auditory attention

- Early research on selective auditory attention suggested that there is very limited processing of unattended stimuli.
- Subsequent research indicated that there is sometimes extensive processing of unattended stimuli.
- There has been controversy as to the location of a bottleneck in processing. Most of the evidence is inconsistent with late-selection theories.
- There has also been controversy as to whether thorough processing of "unattended" stimuli is a result of spillage (Broadbent) or of leakage (Treisman).
- The evidence is not conclusive, but recent findings suggest that spillage may be more important than leakage.

Multitasking

- Mobile-phone use impairs driving performance. It leads to an increase in brake response time and a decreased ability to respond to other drivers.
- When people perform two tasks at the same time, there is nearly always some evidence of interference or disruption. This is seen in the psychological refractory period effect that is still observable even after 10,000 trials.
- Practice typically has a substantial effect on dual-task performance, leading to a marked reduction in interference.

- Practice often results in the development of automatic responses that occur rapidly but suffer from inflexibility.
- Dual-task performance is worse when the two tasks are either difficult or similar to each other.
- According to central capacity theories, dual-task performance depends on the demands that each task imposes on some central capacity. Such theories can account for the effects of practice on dual-task performance, but de-emphasize the role of more specific processing resources.
- According to the multiple-resource model, the processing system consists of independent processing mechanisms having limited capacity. These processing mechanisms are based on distinctions among stages of processing, modalities, codes, and responses. This model can account for many similarity effects but de-emphasizes more general processing resources (e.g., central capacity).

Further Reading

- Bruce, V., Green, P.R., & Georgeson, M.A. (2003). *Visual perception: Physiology, psychology and ecology* (4th ed.). Hove, UK: Psychology Press. Chapter 9 of this outstanding book is devoted to object recognition. In addition, there is full coverage of research on the existence of two visual systems.
- Driver, J. (2001). A selective review of selective attention research from the past century. *British Journal of Psychology*, *92*, 53–78. This article provides a useful historical overview of research on visual attention.
- Eysenck, M.W. (2006). *Fundamentals of cognition*. Hove, UK: Psychology Press. The topics discussed in this chapter are considered at greater length in this textbook.
- Merikle, P.M., Smilek, D., & Eastwood, J.D. (2001). Perception without awareness: Perspectives from cognitive psychology. *Cognition, 79*, 115–134. There is good coverage of research on subliminal perception in this article.
- Morgan, M. (2003). *The space between our ears: How the brain represents visual space*. London: Weidenfeld & Nicolson. Many key issues in visual perception are discussed in this entertaining book.
- Pashler, H., Johnson, J.C., & Ruthroff, E. (2001). Attention and performance. *Annual Review of Psychology*, *52*, 629–651. This article discusses in detail dual-task performance, practice effects, and the development of automatic processes.
- Sekuler, R., & Blake, R. (2005). *Perception* (5th ed.). New York: McGraw-Hill. There is good introductory coverage of numerous topics in perception in this American textbook.
- Simons, D.J., & Rensink, R.A. (2005). Change blindness: Past, present, and future. *Trends in Cognitive Sciences*, *9*, 16–20. The key findings on change blindness are discussed succinctly in this article by two of the leading researchers in the area.

Chapter 7

Contents

Conditioning and learning

7

Compared to most other species, we are extremely good at learning. Learning is of the utmost importance to us in our everyday lives. Adults are much better equipped than children to deal with the complexities of life because they have spent many years acquiring knowledge and skills. Not surprisingly, the study of learning was *the* major focus of research when psychology emerged as a scientific discipline around the start of the twentieth century. This can be seen in the work of Pavlov and the early behaviorists such as John Watson and Fred Skinner (see Chapter 2).

The behaviorists focused mostly on simple forms of learning such as learning to salivate when a bell sounds or learning to press a lever for food reward. Such forms of learning (known as conditioning) involve a person's or an animal's behavior becoming dependent on certain environmental stimuli. We deal initially with the conditioning approach to learning. However, that approach can't account for most human learning. Accordingly, we then move on to consider other forms of learning. First, we discuss observational learning, which involves learning successful ways of behaving by observing the behavior of others. Second, we discuss implicit learning. This is learning apparently occurring in the absence of conscious awareness of what has been learned. Third, we discuss ways in which prolonged practice can lead to the development of expertise.

CLASSICAL CONDITIONING

Imagine you have gone to see your dentist. As you lie down on the reclining chair, you start to feel frightened. Why are you frightened *before* the dentist has caused you any pain? The sights and sounds of the dentist's surgery lead you to expect that you are shortly going to be in pain. Thus, you have formed an *association* between the neutral stimuli of the surgery and the painful stimuli involved in drilling. Such associations are of crucial importance in **classical conditioning**. In essence, the fear created by the drilling is now triggered by the neutral stimuli of the surgery.

Textbook writers nearly always focus on unpleasant everyday examples of classical conditioning (I've just been guilty of that myself!). However, there are also pleasant examples. Most middle-aged people have especially positive feelings for the music that was popular when they were in their teens and early twenties. Associations are formed between the music and various exciting kinds of stimuli encountered during adolescence.

Classical conditioning may be relevant to the development of some phobias, which involve an extreme fear of certain objects (e.g., snakes; spiders). It has been argued that phobias develop when neutral stimuli become associated with stimuli causing fear, leading to the neutral stimuli triggering a fear response (see Chapter 21). Some forms of behavior therapy used in the treatment of mental disorder make use of classical conditioning (see Chapter 22).

BASIC FINDINGS

The best-known example of classical conditioning comes from the work of Ivan Pavlov (1849–1936). Dogs (and other animals) salivate when food is put in their mouths. In technical terms, what we have here is an unlearned or **unconditioned reflex** involving a

Key Terms

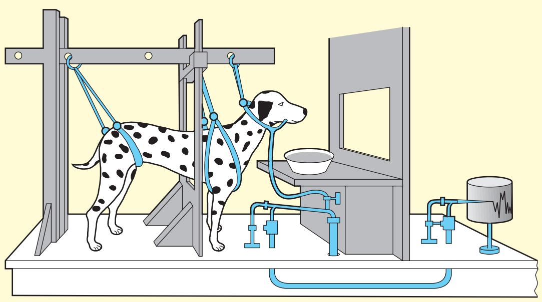
Classical conditioning: a basic form of learning in which simple responses (e.g., salivation) are associated with a new or conditioned stimulus.

Unconditioned reflex: the new association between a stimulus and response formed in classical conditioning.

Learned assciations

Imagine something nice, something delicious, your favorite food. Is it strawberries, chocolate, a barbecue, a curry? Think about it and visualize it, and you will find your mouth is watering! There is no such food nearby, you cannot really see, smell, or taste it, but you have learned that you love this food and this learned association has made you salivate. This will not happen if you are presented with a food you have never seen before, as you have not learned an association to it. If your most disliked sort of food were actually presented to you, your mouth would not water either. A different association would have been learned, and possibly a different response too.

Diagram of the apparatus used by Pavlov for his study of conditioning with dogs (adapted from Yerkes & Morgulis, 1909)



connection between the **unconditioned stimulus** of the food in the mouth and the **unconditioned response** of salivation. Pavlov discovered he could train dogs to salivate to other stimuli (see the figure on the left). In some studies, he presented a tone (a neutral stimulus which became the **conditioned stimulus**) just before food several times, so that the tone signaled the imminent arrival of food. Finally, he presented the same tone (the test stimulus) on its own without any food following, and found the dog salivated to the tone. The dog had acquired a conditioned reflex, in which the conditioned stimulus (the tone) was associated with the unconditioned stimulus (sight of food), and the learned or **conditioned response** was salivation. Note that it is essential for the food to follow very shortly after the tone for a **conditioned reflex** to be formed.

Similar findings have been obtained in numerous studies on humans. In eyeblink conditioning, for example, a tone (conditioned stimulus) is presented shortly before a puff of air (unconditioned stimulus) is administered to the eye. After a series of trials, participants react to the tone with an eyeblink (the conditioned response).

Pavlov discovered several features of classical conditioning in his research on dogs. For example, the conditioned response of salivation was greatest when the tone presented on its own was the same as the tone that had previously been presented just before food. A smaller amount of salivation was obtained when a different tone was used. **Generalization** refers to the fact that the strength of the conditioned response (e.g., salivation) depends on the similarity between the test stimulus and the previous training stimulus. Another phenomenon is **discrimination**. Suppose a given tone is paired several times with the sight of food. The dog will learn to salivate to the tone. Then another tone is presented on its own. It produces a smaller amount of salivation than the first tone through generalization. Next the first tone is paired with food several more times, but the second tone is never paired with food. Salivation to the first tone increases, whereas that to the second tone decreases. Thus, the dog has learned to discriminate between the two tones.

Another key feature of classical conditioning is extinction. When Pavlov presented the tone on its own several times after conditioning had occurred, there was less and less salivation. Thus, the repeated presentation of the conditioning stimulus in the absence of the

Key Terms

Unconditioned stimulus:
a stimulus that produces an **unconditioned response** in the absence of learning.

Unconditioned response:
an unlearned response to an **unconditioned stimulus**.

Conditioned stimulus:
a stimulus that becomes associated through learning with the **unconditioned stimulus**.

Conditioned response:
a response which is produced by the **conditioned stimulus** after a learning process in which the conditioned stimulus has been paired several times with the **unconditioned stimulus**.

Conditioned reflex:
the new association between a stimulus and response formed in **classical conditioning**.

Generalization:
the tendency of a **conditioned response** to occur (but in a weaker form) to stimuli similar to the **conditioned stimulus**.

Discrimination:
the strength of the **conditioned response** to one **conditioned stimulus** is strengthened at the same time as that to a second conditioned stimulus is weakened.

unconditioned stimulus removes the conditioned response (this is **extinction**). Extinction does *not* mean that the dog or other animal has lost the relevant conditioned reflex. Animals brought back into the experimental situation after extinction has occurred produce some salivation in response to the tone (this is **spontaneous recovery**). It shows that the salivary response to the tone was inhibited rather than lost during extinction.

The three stages of classical conditioning

Stage 1: Before conditioning

Conditioned stimulus → No response
Unconditioned stimulus → Unconditioned response

Stage 2: During conditioning

Conditioned stimulus → Unconditioned response
Unconditioned stimulus → Unconditioned response

Stage 3: After conditioning

Conditioned stimulus → Conditioned response

WHAT IS GOING ON?

At first glance, it seems that two factors are of special importance in classical conditioning. First, the conditioned and unconditioned stimuli need to be presented very close together in time. Second, there is a process of stimulus substitution, with the conditioned stimulus simply acting as a *substitute* for the unconditioned stimulus. For example, the sight of the dentist's surgery evokes the fear originally associated with the dentist's drilling.

In fact, the above account is incorrect. So far as the first factor is concerned, it is true that conditioning is greatest when the conditioned stimulus is presented about half a second before the unconditioned stimulus. However, there is little or no conditioning if the order of the stimuli alters so that the unconditioned stimulus is presented shortly before the conditioned stimulus.

Kamin (1969) showed that classical conditioning does *not* always occur when a conditioned stimulus is followed closely by an unconditioned stimulus. The animals in the experimental group received light (conditioned stimulus 1) paired with electric shock, and learned to react with fear and avoidance when the light came on. The animals in the contrast group had no training. Then both groups received a series of trials with a light–tone combination followed by shock. Finally, both groups received only the tone (conditioned stimulus 2). The contrast group responded with fear to the tone on its own, but the experimental group did not.

How can we explain Kamin's (1969) findings? The experimental animals learned that light (conditioned stimulus 1) predicted shock, and so ignored the fact that the tone (conditioned stimulus 2) also predicted shock. The phenomenon of a conditioned stimulus failing to produce a conditioned response because another conditioned stimulus already predicts the arrival of the unconditioned stimulus is known as **blocking**. The contrast animals did learn that the tone predicted shock, because they had not previously learned something different.

What about the notion that the conditioned stimulus acts as a substitute for the unconditioned stimulus? Let us go back to Pavlov's research. When food is presented to a dog, it typically engages in chewing and swallowing as well as salivating (unconditioned response). However, the conditioned stimulus (e.g., tone) produces salivation but *not* chewing and swallowing. In addition, the tone often produces conditioned responses (e.g., tail wagging; looking at the place where food is usually presented) that don't occur in response to the food itself (Jenkins, Barrera, Ireland, & Woodside, 1978). The clear differences between the conditioned and unconditioned responses indicate that the unconditioned stimulus is *not* simply a substitute for the unconditioned stimulus.

Rescorla and Wagner (1972) put forward a very influential theoretical approach to classical conditioning. Their central assumption was that associative learning occurs between a conditioned stimulus and an unconditioned stimulus when the conditioned

Key Terms

Extinction:
the elimination of a response when it is not followed by reward (**operant conditioning**) or by the unconditioned stimulus (**classical conditioning**).

Spontaneous recovery:
the re-emergence of responses over time in **classical conditioning** following experimental extinction.

Blocking:
the failure of a conditioned stimulus to produce a conditioned response because another conditioned stimulus already predicts the presentation of the unconditioned stimulus.

Many caterpillars are poisonous and can be deadly; therefore potential predators must quickly learn not to eat them. If too many are eaten before the predators learn to avoid them, then the brightly colored signaling strategy is not working.

stimulus *predicts* the arrival of the unconditioned stimulus. This assumption allowed them to account for several phenomena. First, if the conditioned stimulus is presented *after* the unconditioned stimulus, it can't predict the arrival of the unconditioned stimulus and so there is little or no conditioning. Second, a second conditioned stimulus that doesn't improve an animal's or a human's ability to predict the arrival of the unconditioned stimulus is redundant and so blocking occurs. Third, dogs in the Pavlov situation respond to a tone by wagging their tails and looking at the place where food is generally presented because they expect food to be presented.

Most of the limitations of the Rescorla–Wagner model occur because it is incorrectly assumed that the strength of conditioned responses accurately reflects the strength of the association between conditioned and unconditioned stimuli (see Miller, Barnet, & Grahame, 1995, for a review). For example, the existence of blocking is taken to mean that the second conditioned stimulus hasn't formed an association with the conditioned stimulus. This is not the case. For example, the blocked conditioned stimulus produces the conditioned response when presented on its own outside the experimental context (Balaz, Gutsin, Cachiero, & Miller, 1982). Another example concerns experimental extinction, which is attributed to unlearning of the association between the conditioned and unconditioned stimuli. The existence of spontaneous recovery means that the association has *not* been unlearned.

ECOLOGICAL PERSPECTIVE

Can we produce conditioned responses equally well with almost any combination of conditioned and unconditioned stimuli? According to psychologists favoring the ecological perspective (e.g., Hollis, 1997), the answer is, "No!" They argue that animals and humans have inherited behavioral tendencies helping them to survive in their natural environment. These behavioral tendencies are often modified through learning to equip animals and humans to cope successfully with their environment. From this perspective, certain forms of learning are more useful than others, and tend to be acquired more easily.

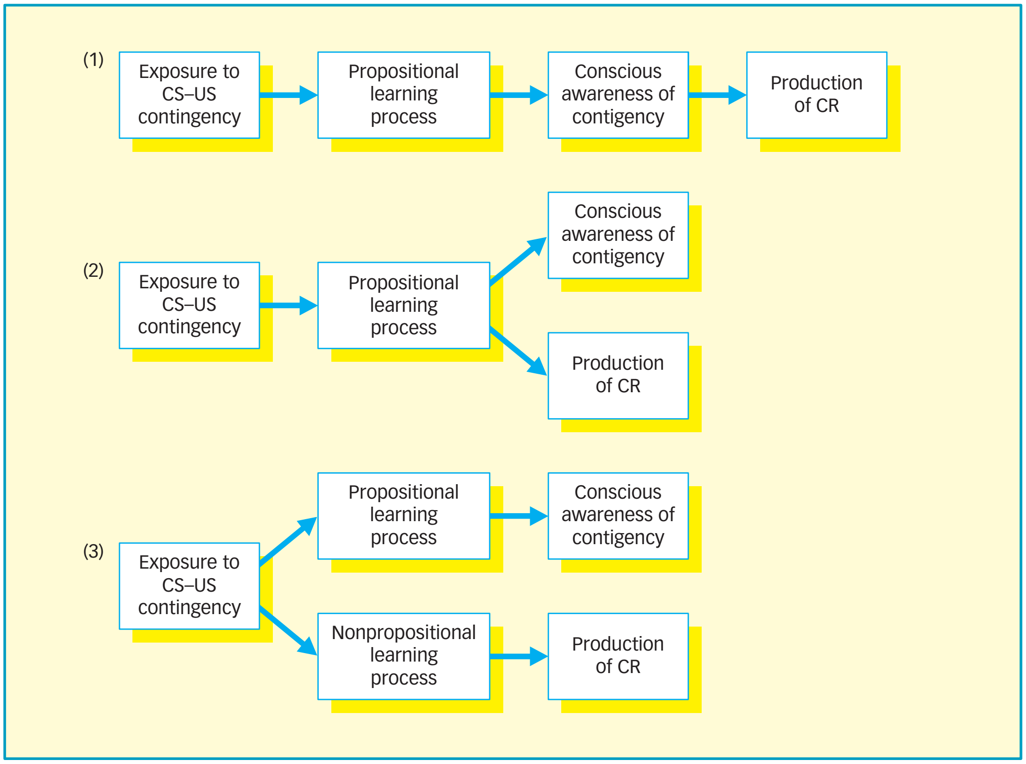
It is essential for the members of all species to avoid poisonous foods, and so the ecological perspective is especially relevant to food-aversion learning. Garcia and Koelling (1966) studied such learning using three conditioned stimuli at the same time: saccharin-flavored water; light; and sound. Some rats had these stimuli paired with the unconditioned stimulus of X-rays, which caused nausea. Other rats had these stimuli paired with a different unconditioned stimulus (electric shock). After that, Garcia and Koelling presented each conditioned stimulus on its own. Rats that had experienced nausea showed an aversion to the flavored water but not to the light or sound cues. In contrast, the rats exposed to electric shock avoided the light and sound stimuli but not the flavored water. Thus, the animals learned to associate being sick with taste, and they learned to associate shock with light and sound stimuli.

What do these findings mean? They indicate there is a biological readiness to associate some stimuli together but not others. For example, there is obvious survival value in learning rapidly to develop a taste aversion to any food followed by illness. This is an example of the phenomenon known as **preparedness**.

IS AWARENESS NECESSARY?

Do we need to be consciously aware of the relationship between the conditioned stimulus and the unconditioned stimulus for conditioning to occur? Lovibond and Shanks (2002) reviewed the relevant evidence. They found that it was relatively rare for studies to report conditioning in the absence of awareness. In those studies, the measures of awareness that were used may well have underestimated conscious knowledge. They also found that the correspondence between conscious awareness and conditioned responses was often fairly weak, indicating that conscious awareness is not *essential* for conditioning to occur. Lovibond and Shanks concluded that the evidence is most consistent with the view that the learning occurring in conditioning experiments has two rather separate consequences: (1) conscious awareness of the relationship between the conditioned and unconditioned stimuli; and (2) production of conditioned responses (see the figure on the following page).

> **Key Term**
>
> **Preparedness:** the notion that each species finds some forms of learning more "natural" and easier than others.

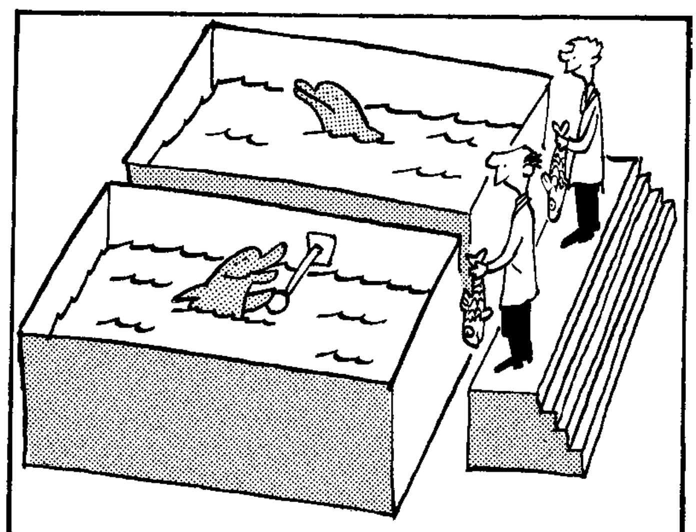


Three models of conditioning and awareness.
CS = conditioned stimulus;
US = unconditioned stimulus;
CR = conditioned response.
From Lovibond and Shanks (2002). Copyright © 2002 by the American Psychological Association. Reprinted with permission.

OPERANT CONDITIONING

In everyday life, people often behave in certain ways when a reward or reinforcement is offered. For example, young people deliver the morning papers because they are paid for doing so, and students work hard at their studies to be rewarded with good marks and improved career prospects. In contrast, we avoid engaging in behavior (e.g., stealing; cheating on exams) likely to be followed by punishment. These are all examples of **operant conditioning**, a form of learning in which behavior is controlled by rewards (also called positive reinforcers) and by unpleasant or aversive stimuli. Much of operant conditioning is based on the **law of effect**: The probability of a given response occurring increases if followed by a reward or positive reinforcer such as food or praise, whereas the probability of a given response decreases if followed by negative consequences.

According to Burrhus Fred Skinner (1904–1990), operant conditioning is of enormous importance. He believed that what we learn and how we behave in everyday life are both very heavily influenced by the conditioning experiences we have had throughout our lives. Operant conditioning has several practical applications. First, it is used extensively in the training of circus animals. Second, operant conditioning is used in the treatment of individuals with mental disorders (Chapter 22). For example, there are token economies in which patients (e.g., schizophrenics) who behave in desirable ways receive tokens that can be exchanged for various rewards. Third, there is biofeedback, which is used in the treatment of conditions such as high blood pressure and migraine.



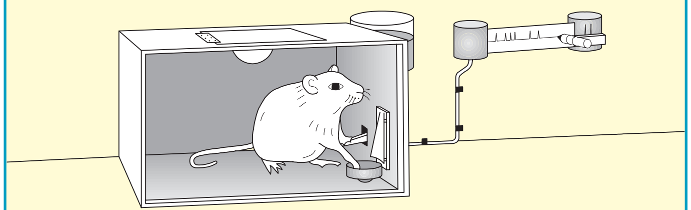
"Well, I simply trained them to give me fish by pressing this over and over again."

Key Terms

Operant conditioning: a form of learning in which behavior is controlled by its consequences (i.e., rewards or positive reinforcers and unpleasant or aversive stimuli).

Law of effect: the probability of a response being produced is increased if it is followed by reward but is decreased if it is followed by punishment.

Skinner box for rats, showing chart recording of lever pressing



On the chart, each vertical line represents a single press on the lever

What happens in biofeedback is that the individual receives a signal whenever a given physiological measure (e.g., heart rate) moves in the desired direction.

BASIC FINDINGS

The best-known example of operant conditioning is provided by the work of Skinner. He placed a hungry rat in a small box (often called a Skinner box; see figure on the left) containing a lever. When the rat pressed the lever, a food pellet appeared. The rat slowly learned that food could be obtained by lever pressing, and so pressed the lever increasingly often. This is a clear example of the law of effect. Skinner found that the effects of a reward or positive reinforcer were greater if it followed shortly after the response had been produced than if it were delayed.

After operant conditioning has occurred, the experimenter can then decrease the probability of the conditioned response (e.g., lever pressing) occurring by removing the positive reinforcer (this is extinction). As with classical conditioning, there is usually some spontaneous recovery after extinction has occurred.

There are two main types of positive reinforcers or rewards: primary reinforcers and secondary reinforcers. **Primary reinforcers** are stimuli needed for survival (e.g., food; water; sleep; air). **Secondary reinforcers** are rewarding because we have learned to associate them with primary reinforcers. Secondary reinforcers include money, praise, and attention.

Key Study

Skinner (1938): Schedules of reinforcement

It seems reasonable to assume that we keep doing things that are rewarding and stop doing things that aren't rewarding. However, Skinner (1938) found some complexities in operant conditioning. So far we have considered continuous reinforcement, in which the reinforcer or reward is given after every response. However, it is rare in everyday life for our actions to be continuously rewarded. Skinner considered what happened with partial reinforcement, in which only some responses are rewarded. He identified four main schedules of partial reinforcement:

- **Fixed ratio schedule**: Every *n*th (e.g., fifth; tenth) response is rewarded. Workers who receive extra money for achieving certain targets are on this schedule.

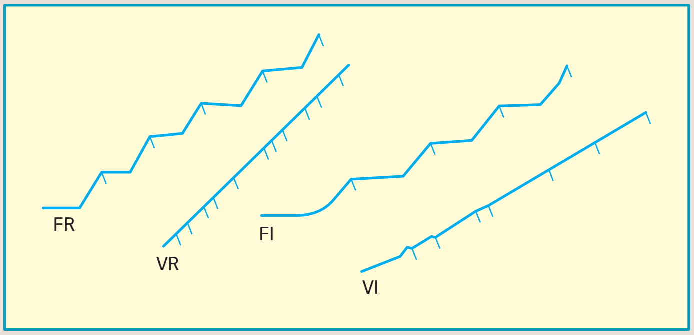
Although these gamblers have no idea when or if they will receive a payout, they continue to play. This is an example of the most successful reinforcement schedule—variable ratio reinforcement.

Key Terms

Primary reinforcers: rewarding stimuli that are needed to live (e.g., food; water).

Secondary reinforcers: stimuli that are rewarding because they have been associated with **primary reinforcers**; money and praise are examples.

Fixed ratio schedule: a situation in which every *n*th response is rewarded.



Typical pattern of responding over time on the four main schedules of partial reinforcement: FR (fixed ratio); VR (variable ratio); FI (fixed interval); and VI (variable interval). From Atkinson et al. (1996). Copyright © by Harcourt Brace. Reproduced with permission.

- **Variable ratio schedule**: On average, every *n*th response is rewarded. However, the actual gap between two rewards may be very small or fairly large. This schedule is found in fishing and gambling.
- **Fixed interval schedule**: The first response produced after a given interval of time (e.g., 60 seconds) is rewarded. Workers who are paid regularly every week are basically on this schedule—they receive reward after a given interval of time, but don't need to produce a specific response.
- **Variable interval schedule**: On average, the first response produced after a given interval of time (e.g., 60 seconds) is rewarded. However, the actual interval is mostly shorter or longer than this. As Gross (1996) noted, self-employed workers whose customers make payments are rewarded at variable intervals, but they don't need to produce a specific response.

The patterns of responding produced by these various schedules are shown in the figure above. It might be thought that continuous reinforcement (with reward available after every response) would lead to better conditioning than partial reinforcement. In fact, the opposite is the case. Continuous reinforcement leads to the *lowest* rate of responding, with the variable schedules (especially variable ratio) leading to very fast rates. This helps to explain why compulsive gamblers often find it difficult to stop their addictive behavior.

What about extinction? Those schedules of reinforcement associated with the best conditioning also show the most resistance to extinction. Thus, rats trained on the variable ratio schedule will keep responding in the absence of reward longer than rats on any other schedule. In contrast, rats trained with continuous reinforcement stop responding the soonest. One reason why continuous reinforcement leads to rapid extinction is that there is a very obvious shift from reward being provided on every trial to reward not being provided at all. Animals trained on the variable schedules are used to reward being provided infrequently and irregularly, and so it takes much longer for them to realize they are no longer going to be rewarded for responding.

Discussion points

1. Can you think of some examples of situations in everyday life involving the various schedules of reinforcement?
2. What are the limitations of Skinner's operant conditioning approach?

In operant conditioning, the animal (or human) has to make the required response before it can be reinforced. How can we condition an animal to produce a complex response it wouldn't produce naturally? The answer is by **shaping**, in which the animal's behavior moves slowly towards the desired response through successive approximations. Suppose we wanted to teach pigeons to play table tennis. To begin with, they would be rewarded for making any contact with the table-tennis ball. Over time, their actions would need to become more and

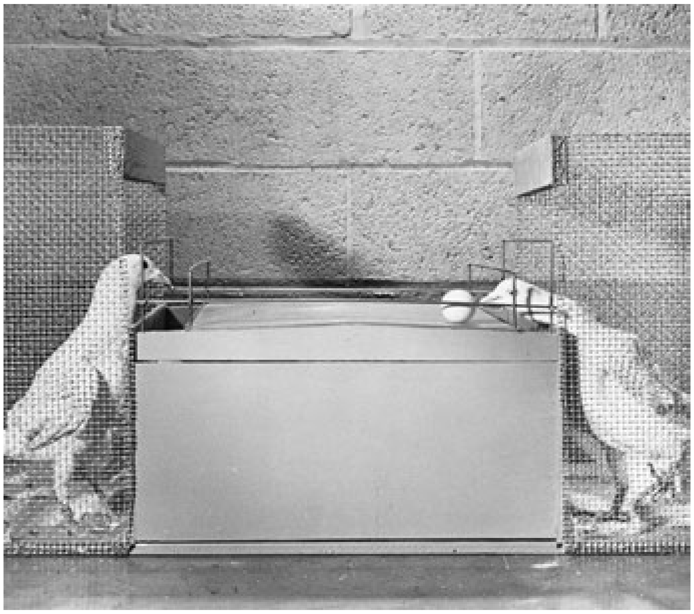
Key Terms

Variable ratio schedule: on average every *n*th response is rewarded, but there is some variation around that figure.

Fixed interval schedule: a situation in which the first response produced after a given interval of time is rewarded or reinforced.

Variable interval schedule: a situation in which the first response produced after a given interval of time is rewarded but with some variation around that time interval.

Shaping: a form of operant conditioning in which behavior is changed slowly in the desired direction by requiring responses to become more and more like the wanted response for reward to be given.



Skinner taught pigeons to play a basic form of table tennis by rewarding them every time they made contact with a table-tennis ball.

more like those involved in playing table tennis for them to be rewarded. In this way, Skinner actually persuaded pigeons to play a basic form of table tennis!

PUNISHMENT: POSITIVE AND NEGATIVE

So far we have considered mainly the effects of positive reinforcers or rewards on performance. However, operant conditioning can also involve unpleasant or aversive stimuli such as electric shocks or failure feedback. Humans and other species learn to behave in ways that reduce their exposure to aversive stimuli just as they learn to increase their exposure to positive reinforcers or rewards. Operant conditioning in which a response is followed by an aversive stimulus is known as **positive punishment** (sometimes simply called punishment). If the aversive stimulus occurs shortly after the response, it has the effect of reducing the likelihood that the response will be produced subsequently. There is also **negative punishment** in which a positive reinforcer or reward is removed following the production of a particular response. For example, a child who refuses to eat properly and starts throwing food on the floor may have the food removed from him/her. The typical effect of negative punishment is to reduce the probability that the punished response will be produced thereafter.

Baron (1977) reviewed the effects of positive punishment on children's aggressive behavior. He identified the following requirements for punishment to reduce aggressive behavior:

1. There should be a very short time interval between the aggressive action and the punishment.
2. Punishment should be relatively strong.
3. Punishment should be applied consistently and predictably.
4. The person giving the punishment shouldn't be seen as an aggressive model.
5. The person receiving punishment should understand clearly why he/she is being punished.

Positive punishment sometimes has various unwanted effects. Gershoff (2002) carried out several meta-analyses to identify the main effects on children of being physically punished by parents. Punishment typically produced immediate compliance to the parent's wishes. However, it was associated with aggressive and antisocial behavior in childhood and adulthood, impaired mental health (e.g., depression), and a tendency to abuse their own children or spouse in adulthood.

Negative punishment is used in the time-out technique. For example, a child who behaves aggressively is prevented from continuing with such behavior by being sent to his/her room. Negative punishment is involved, because the child is removed from pleasurable activities. The time-out technique often improves children's behavior while avoiding the negative effects associated with positive punishment (Rortvedt & Miltenberger, 1994). This is especially the case if parents are firm and relatively unemotional.

Key Terms

Positive punishment:
a form of operant conditioning in which the probability of a response is reduced by following it with an unpleasant or aversive stimulus; sometimes known simply as punishment.

Negative punishment:
a form of operant conditioning in which the probability of a response being produced is reduced by following it with the removal of a positive reinforcer or reward.

Case Study: *Punishment*

Using punishment alone to affect behavior is regarded by most psychologists today as a technique that is morally and ethically dubious. When this belief is added to research that has shown how punishment on its own has at best only short-lived effects, it is surprising that punishments are still used in so many situations, from family life to warring nations.

Many cultures, such as our own, still use punishment to deal with criminal offenders. Fines or prison sentences are serious punishers in their own right, but research suggests that they would be more effective if linked to some kind of reward for not re-offending. Figures from the UK Central Statistical Office (1996) show that punishment alone does not have much success. In England and Wales between 1987 and 1990, three in every five males sent to prison became re-offenders, and in 1991 75% of young male offenders had been reconvicted within 2 years, 12% within 3 months of their release from prison.

AVOIDANCE LEARNING

Nearly all drivers stop at red traffic lights because of the possibility of aversive stimuli in the form of an accident or trouble with the police if they don't. This is a situation in which no aversive stimulus is presented if suitable action is taken, and is an example of **avoidance learning**. Many aversive stimuli strengthen any responses stopping the aversive stimuli being presented; they are known as *negative reinforcers*.

Avoidance learning can be very effective, as was shown by Solomon and Wynne (1953). Dogs were placed in a two-compartment apparatus. A change in the lighting served as a warning that a strong electric shock was about to be presented. The dogs could avoid being shocked by jumping into the other compartment. Most dogs received a few shocks early in the experiment. After that, however, they generally avoided shocks for the remaining 50 or more trials.

Mowrer (1947) proposed two-process learning theory to account for avoidance learning. According to this theory, the first process involves classical conditioning. The pairing of neutral (e.g., walls of the compartment) and aversive stimuli (electric shock) produces conditioned fear. The second process involves operant conditioning. The avoidance response of jumping into the other compartment is rewarded or reinforced by fear reduction.

Two-process theory provides a plausible account of avoidance learning. However, there are problems with the notion that the avoidance response occurs to reduce fear. Dogs in the Solomon and Wynne (1953) study typically responded to the warning signal in about 1.5 seconds, which is probably too little time for the fear response to have developed. After the avoidance response started being produced regularly, the dogs didn't behave as if they were anxious. Thus, it is difficult to argue that their avoidance behavior was motivated *only* by fear reduction.

THEORETICAL PERSPECTIVES

What is learned in operant conditioning? According to Skinner, reinforcement or reward strengthens the association between the discriminative stimulus (e.g., the inside of the Skinner box) and the reinforced response (e.g., lever press). In contrast, Tolman (1959) proposed a more cognitive theory according to which animals learn much more than is implied by Skinner's views. Tolman argued that operant conditioning involves the learning of means–end relationships. A **means–end relationship** is the knowledge that the production of a given response in a given situation will have a specific effect. For example, it might be the knowledge that pressing a lever in the Skinner box will lead to the presentation of a food pellet.

There is much evidence that animals *do* learn means–end relationships. For example, Dickinson and Dawson (1987) trained rats to press a lever to receive sugar water, whereas others were trained to press a lever for dry food pellets. Some of the rats were then deprived of food, whereas others were deprived of water. Finally, all of them were tested under extinction conditions in which no reward was provided. The key findings involved the rats who were thirsty. Those who had been reinforced previously with sugar water produced far more lever presses in extinction than did those who had been reinforced with dry food pellets. The rats used their knowledge of the expected reinforcer to decide how worthwhile it was to press the lever. Thirsty rats wanted something to drink. As a result, the expectation of dry food pellets didn't encourage them to engage in much lever pressing.

Evidence that animals acquire detailed knowledge about the reinforcer to which they have been exposed was reported by Pecoraro, Timberlake, and Tinsley (1999). Rats became accustomed to a certain amount of reinforcement but then started receiving less reinforcement. This produced a **negative contrast effect** involving a marked decrease in response rate. Indeed, these rats had a slower response rate than rats that had received the smaller reinforcement throughout.

Limitations on operant conditioning?

Skinner assumed that virtually any response can be conditioned in any stimulus situation. This is known as **equipotentiality**. Skinner's assumption is false. For example, Breland

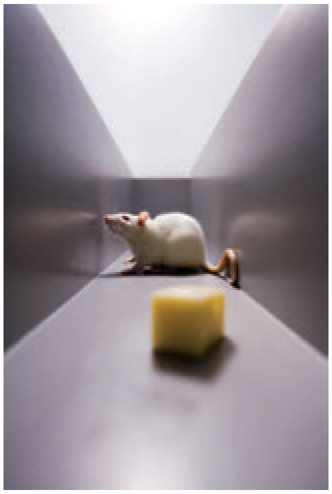
Key Terms

Avoidance learning: a form of **operant conditioning** in which an appropriate avoidance response prevents presentation of an unpleasant or aversive stimulus.

Means–end relationship: the knowledge that responding in a particular way in a given situation will produce a certain outcome.

Negative contrast effect: a marked reduction in response rate in **operant conditioning** when there is a decrease in the size of the reinforcer.

Equipotentiality: the notion in **operant conditioning** that any response can be conditioned in any stimulus situation.



In Gaffan et al.'s 1983 study, the rats avoided revisiting the same arm of a T-maze where they had previously found food. The ecological perspective would predict this behavior.

and Breland (1961) tried to train a pig to insert a wooden token into a piggy bank for reward. The pig picked up the token, but then repeatedly dropped it on the floor. In the words of Breland and Breland, the pig would "root it [turn it up with its snout], drop it again, root it along the way, pick it up, toss it in the air, drop it, root it some more, and so on." They argued that their findings showed evidence of instinctive drift, meaning that what animals learn tends to resemble their instinctive behavior.

Additional evidence that instinctive behavior plays a much larger role in operant conditioning than Skinner believed was provided by Moore (1973). He took films of pigeons pecking at keys for either food or water reward. Students were then asked to decide what the reward was by looking at the films of the pigeons' pecking behavior. They were correct 87% of the time. Birds pecking for food usually struck the key with an open beak, and made sharp, vigorous pecks. When pecking for water, on the other hand, the pigeons had their bills closed and there was a more sustained contact with the key.

Ecological perspective

The evidence discussed above suggests it may be useful to consider operant conditioning from the ecological perspective. According to this perspective, animals should find it easier to learn forms of behavior enabling them to cope with their natural environment. Supporting evidence was reported by Gaffan, Hansel, and Smith (1983). Rats in a T-shaped maze had to decide whether to turn left or right. Suppose a rat turns left and finds food at the end of that arm of the maze. According to conditioning principles, the rat has been rewarded for turning left, and so should turn left on the following trial. However, in the rat's natural environment it is generally not sensible to return to a place from which all the food has just been removed. Gaffan et al. found that rats early in training tended to avoid the arm of the T-shaped maze in which they had previously found food, as predicted from the ecological perspective.

Overall Evaluation

- + Operant conditioning is often very effective. The behavior of humans and other species can be controlled by clever use of reinforcement (e.g., the training of circus animals).
- + Operant conditioning has been used successfully in the treatment of various mental disorders (see Chapter 22).
- − In real life, we don't learn things mainly by performing responses that are rewarded. Instead, we learn an enormous amount simply by *observing* the behavior of other people (Bandura, 1977, see next section). Operant conditioning only accounts for some relatively simple forms of learning.
- − Skinner exaggerated the importance of *external* or environmental factors as influences on behavior and minimized the role of *internal* factors (e.g., goals). As Bandura (1977, p. 27) pointed out, "If actions were determined solely by external rewards and punishments, people would behave like weather vanes, constantly shifting in radically different directions to conform to the whims of others."
- − Operant conditioning often has more effect on performance than on learning. Suppose someone offered you $1 every time you said, "The earth is flat." You might (especially if burdened by debt!) say that sentence hundreds of times, so that the reinforcement or reward would have influenced your performance or behavior. However, it wouldn't affect your knowledge or learning so that you really believed that the earth is flat.
- − Skinner's notion of equipotentiality is incorrect, as is his assumption that operant conditioning is uninfluenced by instinctive behavior. The ecological approach provides an appealing alternative perspective.

OBSERVATIONAL LEARNING

Skinner and other advocates of operant conditioning argued that most human learning requires us to produce responses that are then rewarded or punished. In contrast, Bandura (1977, 1986, 1999) emphasized the importance of **observational learning**. This is learning occurring as a result of observing the behavior of some other person or model. (The relevance of Bandura's approach to the understanding of personality is discussed in Chapter 12 and the effects of observational learning on aggression are considered in Chapter 15).

According to Bandura (1999, p. 170):

> *Humans have evolved an advanced capacity for observational learning that enables them to expand their knowledge and competencies rapidly through the information conveyed by the rich variety of models. Virtually all behavioral, cognitive, and affective learning from direct experience can be achieved vicariously [second-hand] by observing people's actions and the consequences for them.*

Why is observational learning so important to humans? One key reason is because it is typically much more efficient than learning (e.g., operant conditioning) that involves actually experiencing a given situation. In the course of a single day, you can readily observe the behavior of numerous people in hundreds of situations. In contrast, it would be very difficult (or impossible) to put yourself in all of those situations in a short period of time. It can also be safer to observe the fate of others who engage in dangerous actions than to perform the same actions yourself!

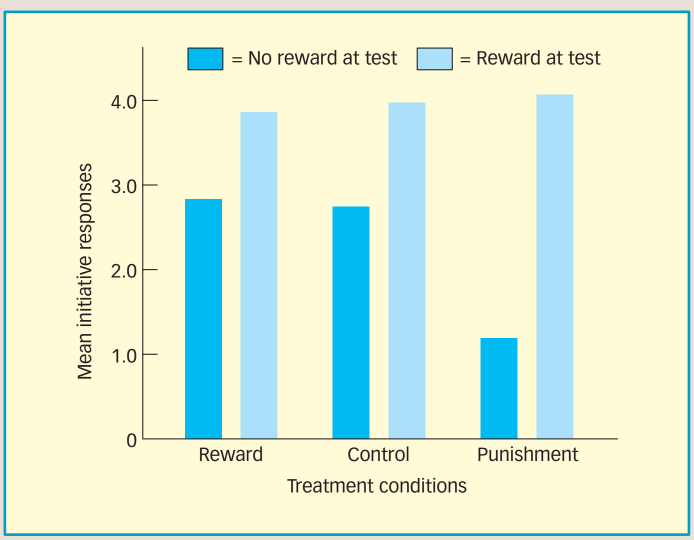
Findings

In a classic study, Bandura (1965) explored the issue of the relationship between observational learning and performance—see the Key Study below.

Key Study

Bandura (1965): Observational learning and the Bobo doll

Young children watched a film in which an adult model behaved aggressively towards an inflatable Bobo doll (it has a weight in the bottom that makes it bob back up when it is knocked down). In one condition, a second adult appeared towards the end of the



Imitation of aggressive behavior by children as a function of the way an aggressive adult was treated (reward, control, punishment) and whether the children were or were not rewarded at the test for imitating the adult's aggressive behavior. Data from Bandura (1965).

Key Term

Observational learning: learning occurring as a consequence of watching the behavior of another person (often called a model).

Adult "models" and children attack the Bobo doll.

film and gave the model some sweets and a soft drink for having put up a "championship performance" (reward condition). In a second condition, the second adult scolded and spanked the model for behaving aggressively (punishment condition). In a third condition, the model didn't receive reward or punishment (control condition).

Bandura (1965) then observed the behavior of the children in the presence of the Bobo doll. Children in the reward and control conditions imitated more of the aggressive actions of the model than did the children in the punishment condition (see the figure above). It could be argued that children in the punishment condition had not achieved much observational learning. However, when children in that condition were offered some fruit juice and toys for showing what they had learned from the adult model, they exhibited as much observational learning as the children in the other two conditions.

Discussion points

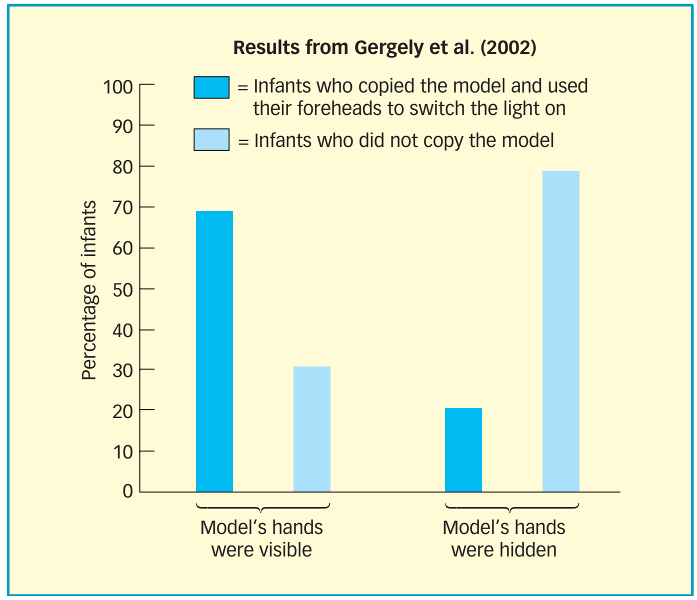
1. What are some of the limitations of this famous research by Bandura?
2. How important do you think observational learning is with respect to producing aggressive behavior?

KEY STUDY EVALUATION

In his classic Bobo doll study, Bandura controlled the behavior of his adult models. They used novel actions such as hitting the doll with a hammer, or throwing it in the air and saying "Pow! Boom!" These actions were chosen because the children would be unlikely to behave like this spontaneously, so that if the actions were produced, the researchers could be fairly confident that the children were imitating the adult model. Bandura's (1965) study is more limited than generally acknowledged. He found that children readily imitated aggressive behavior towards a doll. However, children are much less likely to imitate aggressive behavior towards another child. In addition, the Bobo doll bounces back up when knocked down, which gives it novelty value. Children unfamiliar with the Bobo doll were five times more likely to imitate aggressive behavior against it than those who had played with it before (Cumberbatch, 1990).

Meltzoff (1988) apparently obtained strong evidence for observational learning. Infants of 14 months watched while an adult model turned on a table-mounted pressure-sensitive light using her forehead. This produced high levels of observational learning—1 week later, two-thirds of the babies used their forehead to turn on the light. This is an impressive finding given that babies rapidly discover how to use their hands to change the environment.

In an important study, Gergely, Bekkering, and Kiraly (2002) showed that the findings from Meltzoff's (1988) study are less conclusive than they seem (see the figure on the right). In that study, the model's hands were on the table, and so the infants could see she had deliberately preferred to use her forehead rather than her hands to turn the light on. Gergely et al. included a second condition in which the adult model pretended to be cold and so had her hands under the table wrapped in a blanket. This apparently small change had a dramatic effect on the results. When the model's hands were free, 69% of the infants (who were 14 months old) copied her behavior by using their forehead to put on the light. In contrast, when the model's hands were *not* free, only 21% of the babies copied her behavior.



Observational learning in infants is strongly influenced by the context.

What can we conclude from Gergely et al.'s (2002) study? First, the findings indicate that observational learning is more complex than suggested by Bandura. According to Bandura, children who observe a model performing an action that is successful or rewarded should imitate that action. However, that simply didn't happen in the condition in which the model's hands were under the blanket.

Second, the findings suggest that even infants are capable of fairly complex processing. The infants had already learned from experience that hands are very useful for touching objects and altering the environment. As a result, observational learning only influenced their behavior when they believed the model had *deliberately* preferred to use her forehead rather than her hands to turn on the light. According to Gergely et al. (2002, p. 755), "Imitation by 14-month-olds goes beyond emulation [imitation]. We conclude that the early imitation of goal-directed actions is a selective, inferential process that involves evaluation of the rationality of the means in relation to the constraints of the situation."

Third, it needs to be borne in mind that the infants in Gergely et al.'s (2002) study were only 14 months of age. If their tendency to imitate (or not to imitate) a model depends on complex thought processes, then this will be even more true of older children. Thus, we must consider cognitive processes at all ages to understand things as apparently simple as observational learning and imitation.

Similar findings were reported by Schwier et al. (2006). Twelve-month-olds observed an adult make a toy animal perform a particular action to reach a goal. In one condition, there was a barrier in the way that forced the adult to make that action. In the other condition, there was no barrier and the adult freely chose to make that action. The infants imitated the adult's action much more often when the adult had freely chosen it than when she was forced to use it. The take-home message is that even infants show some ability to consider the actor's *intention* as well as his/her behavior, and use that information to decide how closely to imitate the actor's behavior (see Fenstermacher and Saudino, 2006, for a review).

Is observational learning as effective as learning based on actually performing the behavior in question? Evidence that it is was reported by Blandin and Proteau (2000). Participants performed a four-segment timing task under one of three conditions: (1) prior observational learning; (2) prior physical practice; and (3) no prior experience. Observational learning and prior physical practice led to comparable levels of performance that were significantly higher than those shown by controls. In addition, participants in the observational learning condition developed error correction mechanisms at least as effective as those developed by participants in the physical practice condition.

Evaluation

- \+ Observational learning occurs very often in children and in adults.
- \+ Observational learning can have powerful effects on subsequent behavior comparable in size to learning based on actual performance (e.g., Blandin & Proteau, 2000).
- – The findings of Gergely et al. (2002) and Schwier et al. (2006) indicate that observational learning doesn't always lead to simple, mindless imitation of a rewarded model. Instead, even infants take account of factors such as the actor's intention and situational constraints on the model's behavior.
- – There is only modest evidence for observational learning in children's acquisition of language. They initially produce much shorter utterances than adults, and rapidly move on to producing novel utterances (see Chapter 13). Neither of these aspects of children's language seems to involve observational learning.
- – As Fenstermacher and Saudino (2006) pointed out, there are substantial (and largely unexplained) individual differences in imitative behavior following observational learning. For example, Fouts and Click (1979) found that extraverted children imitated modeled behavior more than introverted ones, possibly because the extraverted children pay more attention to social stimuli.

IMPLICIT LEARNING

Do you think you could learn something without being aware of what you had learned? It sounds improbable. For example, suppose you went to a lecture on social psychology yesterday. No matter how boring the lecture was, I imagine you learned some useful new information about social psychology. You can probably bring to mind some of that information and you have a strong conscious awareness of having learned certain things. In that context, the notion of learning without conscious awareness seems very suspect. Moreover, if we *did* acquire information without any conscious awareness, it might seem somewhat pointless and wasteful—if we don't realize we have learned something, then it appears unlikely we are going to be able to make much use of it.

In the terms used by psychologists, we have started to discuss **implicit learning**, which is, "Learning without conscious awareness of having learned" (French & Cleeremans, 2002, p. xvii). Implicit learning can be contrasted with **explicit learning**, which involves conscious awareness of what has been learned. We have just dismissed the notion of implicit learning, but (as so often in psychology) there is another side to the story. Consider the following fuller definition of implicit learning offered by Cleeremans and Jiménez (2002, p. 20): "Implicit learning is the process through which we become sensitive to certain regularities in the environment (1) in the absence of intention to learn about these regularities; (2) in the absence of awareness that one is learning; and (3) in such a way that the resulting knowledge is difficult to express." You can probably think of skills you possess that are hard to express in words. For example, it is notoriously difficult to express what we know about riding a bicycle. Indeed, the verbal descriptions most people give of how to steer a bicycle around a corner are inaccurate and would lead anyone following them to fall off pretty quickly! Another example is that most of us speak reasonably grammatically even though we have little or no conscious access to the grammatical rules in the English language.

One of the tasks most used to study implicit learning is artificial grammar learning. In a typical study (e.g., Reber, 1967), participants are initially asked to memorize meaningless letters strings (e.g., PVPXVPS; TSXXTVV). After that, they are told that the memorized letter strings all follow the rules of an artificial grammar, but they aren't told the nature of these rules. Next, the participants classify *novel* strings as grammatical or ungrammatical. Finally, they are asked to describe the rules of the grammar.

Key Terms

Implicit learning: learning information without conscious awareness of having learned; see **explicit learning**.

Explicit learning: learning that involves conscious awareness of what has been learned; see **implicit learning**.

What is typically found from studies on artificial grammar learning? First, the classification task is performed significantly above chance level, thus indicating that some learning has occurred. Second, the participants cannot describe the grammatical rules when asked to do so. This combination of learning plus an inability to express what has been learned seems superficially to fit Cleereman and Jiménez's definition of implicit learning very neatly. Alas, as we will see, there has been much controversy about the proper interpretation of findings from the artificial grammar task.

ROLE OF CONSCIOUSNESS

At the heart of the controversy over implicit learning is the issue of the importance of conscious awareness in human learning and behavior. Cleereman and Jiménez (2002) identified two extreme positions on this issue. One extreme is the notion of a "Commander Data" type of consciousness based on Star Trek's character Data. He is an android [robot resembling a human being] who can describe his internal states in enormous detail. Commander Data theorists assume that consciousness has great power and that any knowledge expressed through behavior is available to it. The opposite extreme is the notion of a zombie consciousness in which we have no conscious awareness of the knowledge influencing our behavior. According to Cleeremans and Jiménez (2002), neither extreme position is plausible. What is most likely is that consciousness is sometimes (but by no means always) of relevance to learning and to human cognition.

EXPERIMENTAL APPROACHES

There are three main experimental approaches to implicit learning, all of which are discussed below:

1. Studies designed to see whether healthy individuals can learn fairly complex material in the absence of conscious awareness of what they have learned.
2. Studies on brain-damaged patients with amnesia, in which the focus is on whether their implicit learning is essentially intact even though their explicit learning is severely impaired. If so, it would suggest that different processes underlie implicit and explicit learning.
3. Brain-imaging studies: If implicit and explicit learning are different forms of learning, then different brain areas should be active during implicit and explicit learning.

Be warned that the findings from all three approaches are nothing like clear-cut!

Complex normal learning

How do we know when learning is implicit? A key problem is that the failure of participants when questioned to indicate conscious awareness of what they have learned (e.g., on an artificial grammar learning task) does *not* necessarily prove that their learning

Implicit learning

How do you know which faucet to turn on when you want hot water? How do you know where a light switch is at home—just putting out your hand without actually thinking about it? According to Howard (2006) this sort of knowledge is gained by implicit learning, and it "happens when people are just going about their daily business, when they are focused on living, not on memorizing or on learning per se."

One of her studies has research participants taking a computer-based test in which they predict as quickly as they can where the next in a sequence of moving dots will appear on the screen. Some of these occur in a predictable pattern or location, and some are random.

What the participants are not told is that some of the events occur in a predictable location or pattern, whereas others are completely random. Most participants are not consciously aware that some dots appear predictably, and yet they begin to respond faster and more accurately to the predictable events than to the random ones. This means that they have learned this without knowing it, which is implicit learning. We do this all the time in everyday life, enabling us to adapt to new situations and people.

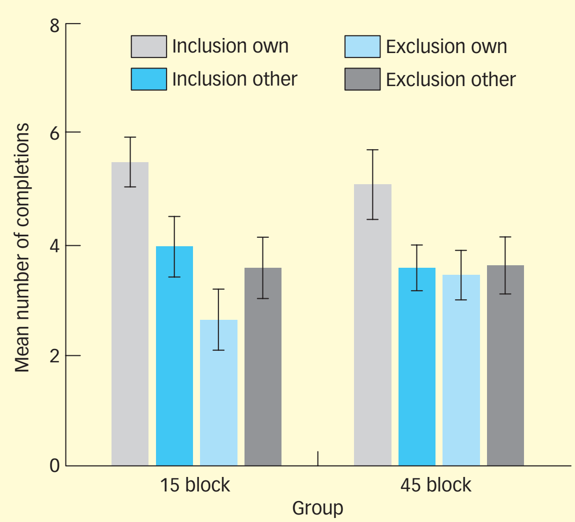
was implicit. Shanks and St. John (1994) argued that two criteria need to be met to show the existence of implicit learning:

1. *Information criterion*: The information participants are asked to provide on the awareness test must be the information responsible for the improved level of performance.
2. *Sensitivity criterion*: "We must be able to show that our test of awareness is sensitive to all of the relevant knowledge" (Shanks & St. John, 1994, p. 374). People may be consciously aware of more task-relevant knowledge than appears on an insensitive awareness test, and this may lead us to underestimate their consciously accessible knowledge.

Shanks and St. John (1994) also discussed what they called the "retrospective problem." Participants may be consciously aware of what they are learning at the time, but have simply forgotten by the end of the experiment when questioned about their conscious awareness.

The serial reaction time task has been used in many studies (e.g., Nissen & Bullemer, 1987) on implicit learning. There are typically dozens or hundreds of trials on this task. On each trial, a stimulus appears at one out of several locations on a computer screen, and the participant responds as rapidly as possible with the response key corresponding to its location. There is a complex repeating sequence over trials in the various stimulus locations, but participants are not told this. Towards the end of the experiment, there is a block of trials conforming to a *novel* sequence. Participants typically respond more rapidly to stimuli in the repeating sequence than to those in the novel sequence, indicating they have learned information about the repeating sequence. However, when questioned at the end of the experiment, participants usually show *no* conscious awareness that there was a repeating sequence.

Evidence that participants have *some* conscious awareness of what they have learned on the serial reaction time task was reported by Wilkinson and Shanks (2004). Participants received either 1500 (15 blocks) or 4500 (45 blocks) trials on the task and showed clear evidence of sequence learning. They were then told there had been a repeating sequence, following which they were presented on each of 12 trials with part of the sequence under one of two conditions. In the *inclusion* condition, they guessed the next location in the sequence. In the *exclusion* condition, they were told to *avoid* guessing the next location in the sequence. If sequence knowledge is totally implicit, then performance shouldn't differ between the inclusion and exclusion conditions. If it is partly explicit, then guesses in the inclusion condition should correspond more often to the actual sequence than those in the exclusion condition. The findings indicated that some explicit knowledge was acquired on the serial reaction time task (see the figure below).



Mean number of completions (guessed locations) corresponding to the trained sequence (own) or the untrained sequence (other) in inclusion and exclusion conditions as a function of number of trials (15 vs. 45 blocks). From Wilkinson and Shanks (2004). Copyright © American Psychological Association. Reprinted with permission.

What about the artificial grammar learning task described earlier? Alas, people's ability to discriminate above chance between grammatical and ungrammatical letter strings does *not* prove they have acquired knowledge of the underlying grammatical rules. Indeed, Channon et al. (2002) found that participants' decisions on the grammaticality of letter strings didn't depend at all on knowledge of grammatical rules. Instead, they classified letter strings as grammatical when they shared letter pairs (bigrams) with the letter strings memorized initially and as ungrammatical when they did not. Thus, participants' above-chance performance when classifying letter strings may well depend on conscious awareness of two-letter fragments relevant to the grammatical rules even though they have no direct knowledge (explicit or implicit) of the rules themselves.

Evaluation

+ Many of the findings provide some (albeit controversial) evidence of implicit learning.

+ Evidence that explicit learning plays some role in explaining performance improvement with practice does *not* mean that no implicit learning has occurred. Indeed, implicit learning may often precede explicit learning, with explicit knowledge being based on previous implicit learning (Sun, Slusarz, & Terry, 2005).

− Research on the artificial grammar learning and serial reaction time tasks is mostly inconclusive because it is not clear that the information and sensitivity criteria have been satisfied.

Learning in amnesics

Amnesic patients (who have severe problems with long-term memory because of brain damage) have impaired explicit memory (involving conscious recollection) but not implicit memory (not involving conscious recollection; see Chapter 8). If amnesic patients have impaired explicit learning but intact implicit learning, that would provide ammunition for those claiming that implicit learning is very different from explicit learning. Why are implicit learning and implicit memory discussed in separate chapters? One reason is because remarkably little research has considered both within a single study. Another reason is that studies of implicit learning have typically used fairly complex novel stimuli, whereas studies of implicit memory have used simple and familiar ones.

Knowlton, Ramus, and Squire (1992) carried out an early study on implicit learning in amnesic patients using the artificial grammar learning task. Amnesic patients had impaired explicit learning on this task but their implicit learning was comparable to that of healthy controls. Different findings were obtained by Channon et al. (2002) in a study mentioned earlier in which they used complex versions of the artificial grammar learning task. Amnesic patients and healthy controls failed to learn the underlying abstract rules of grammar, but did learn about fragments (e.g., letter pairs). The key finding was that amnesic patients learned fewer fragments than the normal controls, suggesting that they had poorer implicit learning.

Findings apparently contradicting those of Channon et al. (2002) were reported by Meulemans and Van der Linden (2003). They used an artificial grammar learning task in which the test of implicit learning was such that fragment knowledge couldn't influence the accuracy of grammaticality judgments. They also used a test of explicit learning on which participants wrote down 10 letter strings they considered to be grammatical. The amnesic patients did much worse than controls on explicit learning, but they performed at a comparable level to controls on implicit learning. Similar findings on the serial reaction time task were reported by Nissen, Willingham, and Hartman (1989).

Evaluation

- ⊕ Most findings suggest that amnesic patients have intact implicit learning but impaired explicit learning. This pattern is consistent with the notion that different mechanisms underlie explicit and implicit learning.
- ⊖ In spite of several positive findings, the implicit learning performance of amnesic patients is sometimes worse than that of normal controls (e.g., Channon et al., 2002).
- ⊖ We don't always know *what* information is being used by amnesics to perform implicit learning tasks. When we lack this information, it is hard to assess whether implicit or explicit learning is involved.

Brain-imaging research

If separate cognitive systems underlie explicit and implicit learning, different brain regions should be activated for these two types of learning. More specifically, since conscious awareness is associated with brain areas within the prefrontal cortex such as the anterior cingulate and the dorsolateral prefrontal cortex (see Chapter 5), these areas should be much more active during explicit learning than implicit learning.

As you may have guessed, the evidence is somewhat inconsistent. Positive findings were reported by Grafton, Hazeltine, and Ivry (1995) on a task involving learning motor sequences. Explicit learning was associated with more activation in the anterior cingulate and areas in the parietal cortex involved in voluntary attention than was implicit learning. Aizenstein et al. (2004) also obtained positive findings using a version of the serial reaction time task. The explicit task involved learning a sequence of shapes. At the same time, the colors of the shapes used in the explicit task formed a sequence that was used on the implicit learning task. Some brain regions were activated during both explicit and implicit learning. However, there was greater prefrontal activation with explicit than with implicit learning, which is precisely in line with prediction.

Negative findings were reported by Schenden, Searl, Melrose, and Stern (2003) in a study on implicit and explicit sequence learning. Both forms of learning activated the same brain areas. Schenden et al. (2003, p. 1020) concluded that, "Both implicit and explicit learning of higher order sequences involve the MTL [medial temporal lobe] structures implicated in memory functions."

Evaluation

- ⊕ There is some evidence that explicit and implicit learning are associated with activation in different brain areas.
- ⊕ There is suggestive evidence that brain areas known to be involved in conscious awareness and attention are more activated during explicit learning than during implicit learning.
- ⊖ At present, the available evidence is sufficiently inconsistent and sparse that no very firm conclusions are possible.

SUMMARY AND CONCLUSIONS

Much of the available behavioral evidence from healthy individuals and from amnesic patients suggests that implicit learning exists and is separate from explicit learning, and the same is true to a lesser extent of brain-imaging evidence from healthy controls. The main counter-argument is that very few studies satisfy the information and sensitivity criteria and avoid the retrospective problem, and so we can't be confident about the validity of the findings. Those skeptical of the existence of implicit learning emphasize the fact that evidence of explicit learning has been found in many studies allegedly focusing on implicit learning. However, finding that *some* explicit learning is involved in performance of a given task doesn't necessarily mean that *no* implicit learning was involved. It seems likely that performance of many tasks depends on a combination of explicit and implicit learning (Sun et al., 2005).

HOW DO YOU BECOME AN EXPERT?

Anyone wanting a successful career soon discovers that a very considerable amount of learning is required. More specifically, it is essential for them to develop **expertise**, which can be defined as "highly skilled, competent performance in one or more task domains [areas]" (Sternberg & Ben-Zeev, 2001, p. 365).

What makes an expert? Most people (including many psychologists) argue that a high level of intelligence is of key importance in the achievement of real expertise. Just think for a moment whether you agree. If you do, you may be surprised to discover that there is evidence suggesting some real experts have only average levels of intelligence. For example, Ceci and Liker (1986) studied individuals with great expertise about harness racing. Harness racing (which is popular in the United States) involves horses pulling a sulky (a light two-wheeled cart) holding one person (the driver). Ceci and Liker identified 14 experts and 16 nonexperts. However, the term "nonexperts" is a relative one in this context, because they knew a vast amount about harness racing and attended horse races nearly every day. The IQs of the experts ranged from 81 to 128, and those of the non-experts from 80 to 130. Four of the experts had IQs in the low 80s, which is well below the population mean of 100.

The experts and nonexperts were given information about 50 unnamed horses and an unnamed standard horse. Fourteen pieces of information were provided in each case (e.g., each horse's lifetime speed; race driver's ability; track size). The participants worked out the probable odds for 50 comparisons with each horse in turn being compared against the standard horse. The experts' performance was outstanding, and superior to that of the nonexperts. They took account of complex interactions among up to seven variables at the same time. Thus, the significance of any one piece of information was interpreted in the context of several other pieces of information about the same horse. It would require complicated statistical formulae to express these interactions mathematically.

The key finding was that the experts' high level of performance didn't depend at all on a high IQ—the correlation between their performance and IQ scores was −.07. Thus, experts with very low IQs were successful at combining information in extremely complex ways. Ceci and Liker (1986) concluded that IQ is unrelated to many forms of intelligent behavior. However, all the experts had devoted thousands of hours to developing their expertise, and Ceci and Liker may have exaggerated the complexity of the knowledge they possessed.

Dramatic findings have also been obtained from individuals patronizingly known as **idiot savants** (knowledgeable idiots) (see Howe, 1998, for a review). Idiots savants generally have mental retardation and low IQs, but they possess some special expertise. For example, they can work out in a few seconds the day of the week corresponding to any specified date in the past or the future, or they perform complex multiplications at high speed, or they know the value of pi to thousands of places of decimals.

In spite of impressive findings like those just described, we need to be aware of their limitations. The expertise (harness racing; exceptional memory; calculating power) is very narrow and specific, and intelligence or IQ is much more likely to be important when we consider broad and general expertise. This was shown in a review article by Gottfredson (1997) on IQ and long-term career success (see Chapter 11). The correlation between intelligence and work performance was only +.23 with low-complexity jobs (e.g., shrimp picker; corn-husking machine operator). However, with high-complexity jobs (e.g., biologist; city circulation manager), the correlation between intelligence and job performance rose to +.58, indicating that intelligence is an important determinant of

Key Terms

Expertise:
the specific knowledge an expert has about a given domain (e.g., that an engineer may have about bridges).

Idiot savants:
individuals who have limited outstanding expertise in spite of being mentally retarded.

success in such jobs. Mackintosh (1998) reviewed evidence showing that the average IQ is about 120–130 (top 15% of the population) for those in very complex occupations (e.g., accountants; lawyers; doctors; even academics!). Thus, high intelligence is of real importance for obtaining (and succeeding in) occupations of high complexity requiring high levels of general expertise.

CHESS PLAYING

In this section we focus on chess-playing expertise. According to Gobet, deVoogt, and Retschitzki (2004), there are several reasons why it is useful to study chess players. First, we can assess very precisely chess players' level of skill. Second, expert chess players develop specific cognitive skills (e.g., pattern recognition; selective search) that are useful in many other areas of expertise. Third, information about chess experts' remarkable memory for chess positions generalizes very well to many other types of expertise.

Everyone accepts that huge amounts of practice are essential in the development of the chess-playing skills of a grandmaster. However, working out *exactly* what expert chess players know that nonexpert players don't is hard to do. A breakthrough came with the influential research of De Groot (1965). He found that expert players were much better than nonexpert ones at remembering chess positions. He gave his participants brief presentations (between 2 and 15 seconds) of board positions from actual games. After removing the board, De Groot asked them to reconstruct the position. Chess masters recalled the positions very accurately (91% correct) whereas less expert players made many errors (only 41% correct). These findings were *not* obtained because chess masters have generally better memories—they were no better than nonexperts at recalling *random* chess positions.

Chunks or templates?

How do chess players use their knowledge to memorize chess positions? According to Chase and Simon (1973), they break chess positions down into about seven chunks or units corresponding to information previously stored in long-term memory. In contrast, Gobet and Waters (2003) argued that the low-level chunks used frequently by chess players develop into more complex (and more flexible) structures known as templates. A **template** is a schematic structure more general than actual board positions. It consists of a *core* (very similar to the information stored in chunks) plus *slots* (containing variable information about pieces and locations).

According to template theory (Gobet & Waters, 2003), chess positions are typically stored in three templates, with each template storing information relating to about 10 pieces. It is assumed that outstanding chess players owe their excellence mostly to their superior template-based knowledge of chess and their ability to form larger templates. This knowledge can be accessed rapidly, thus allowing them to narrow down with great speed the possible moves they need to consider. Finally, it is predicted that expert chess players will have better recall of random chess positions than nonexperts, because some patterns relating to stored templates occur by chance even in random positions.

Most findings support template theory. Gobet and Clarkson (2004) found that the superior recall of chess-board positions by expert players was a result of the larger size of their templates—the maximum template size was about 13–15 for masters compared to only six for beginners. The number of templates didn't vary as a function of playing strength and averaged out at about two, close to the predicted figure of three.

According to template theory, individual differences in chess-playing ability are a result more of differences in template-based knowledge than of the ability to search successfully through possible moves. Relevant evidence was reported by Burns (2004). He used information about expert chess players' performance in normal competitive games and in blitz chess, in which the entire game has to be completed in 5 minutes (less than 5% of the time available in normal chess). The key assumption was that any player's performance in blitz chess must depend mainly on his/her template-based knowledge because there is so little time to engage in relatively slow search processes. Thus,

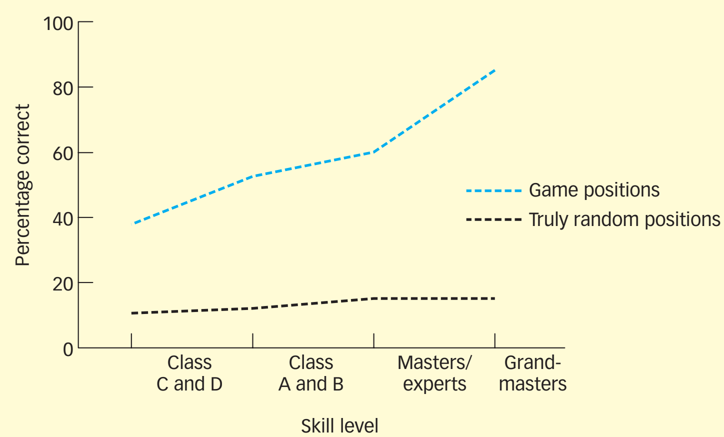
Key Term

Template:
as applied to chess, an abstract, schematic structure consisting of a mixture of fixed and variable information about chess pieces.

template-based knowledge is readily available to players in both blitz and normal chess, whereas search processes are much more available in normal chess than in blitz chess. If template theory is correct, then players performing best in normal chess should also perform best in blitz chess—the reason is that the key to successful chess (i.e., template-based knowledge) is available in both forms of chess.

What did Burns (2004) find? Performance in blitz chess correlated highly with performance in normal chess. In three samples, the correlation varied between +.78 and +.90, indicating that template theory is correct in emphasizing the importance of template-based knowledge. However, we must *not* draw the conclusion that search processes are irrelevant—the same players playing chess under normal conditions and under blitz conditions made superior moves in the former condition that provided time for much slow searching.

Gobet and Waters (2003) tested the prediction that experts will recall random chess positions better than nonexperts. Their findings supported template theory (see the figure below): the number of pieces recalled was significantly higher for the most expert players than for the least expert ones.



Percentage of pieces correctly recalled by class C and D players (weak club standard), class A and B players (moderate or strong club players), masters/experts, and grandmasters. Adapted from Gobet and Waters (2003).

Evaluation

+ Outstanding chess players possess much more template-based knowledge of chess positions than nonexperts; this knowledge allows them to assess chess positions very rapidly.

+ Template theory provides an explanation for the effective performance of experts playing blitz chess and their superior ability to recall random chess positions.

− Charness (1981) found that experts and grandmasters think about five moves ahead whereas class D players (who have a low level of skill) think only an average of 2.3 moves ahead. This difference cannot be readily accounted for in terms of template knowledge.

− Hatano and Inagaki (1986) distinguished between **routine expertise** (involved when a player can solve familiar chess problems rapidly and efficiently) and **adaptive expertise** (involved when a player has to develop a strategy when confronted by a novel board position). Template theory provides a convincing account of what is involved in routine expertise, but doesn't shed much light on adaptive expertise.

Key Terms

Routine expertise: using acquired knowledge to develop strategies for dealing with novel problems; see **adaptive expertise**.

Adaptive expertise: using acquired knowledge to solve familiar problems efficiently; see **routine expertise**.

DELIBERATE PRACTICE

We all know that prolonged and carefully organized practice is essential in the development of *any* kind of expertise. However, what we really need is a theory spelling out the details of what is involved in effective practice. Precisely that was done by Ericsson and Lehmann (1996), who emphasized that a wide range of expertise can be developed through deliberate practice. **Deliberate practice** has four aspects:

1. The task is at an appropriate level of difficulty (not too easy or too hard).
2. The learner is given informative feedback about his/her performance.
3. The learner has adequate chances to repeat the task.
4. The learner has the opportunity to correct his/her errors.

What exactly happens as a result of prolonged deliberate practice? According to Ericsson and Kintsch (1995), experts can get round the limited capacity of working memory. They proposed the notion of **long-term working memory:** Experts learn how to store relevant information in long-term memory so it can be accessed readily through retrieval cues held in working memory. This doesn't mean that experts have greater working memory capacity than the rest of us. Rather, they are more efficient at combining the resources of long-term memory and working memory.

Where the approach adopted by Ericsson and Lehmann (1996) becomes controversial is in the additional assumption that deliberate practice is *all* that is needed to develop expert performance. Thus, innate talent or ability is said to have practically no influence on expert performance.

Findings

Evidence supporting the theory was reported by Ericsson, Krampe, and Tesch-Römer (1993) who studied violinists in a German music academy. The key difference between 18-year-old students having varying levels of expertise on the violin was the amount of deliberate practice they had had over the years. The most expert violinists had spent on average nearly 7500 hours engaged in deliberate practice compared to the mere (!) 5300 hours clocked up by the good violinists.

A potential problem with the study by Ericsson et al. (1993) is that their evidence was correlational and so doesn't prove that deliberate practice *caused* the higher level of performance. Perhaps those musicians with the greatest innate talent and/or musical success chose to spend more time practicing than those with less talent. However, some evidence goes against that interpretation. Sloboda, Davidson, Howe, and Moore (1996) compared highly successful young musicians with less successful ones. The two groups didn't differ in the amount of practice time they required to achieve a given level of performance.

Is it really true that innate ability or IQ is irrelevant to the development of expertise? This issue was addressed by Hulin, Henry, and Noon (1990), who combined the data from numerous studies. There were two key findings:

1. The correlation or association between IQ and performance *decreased* steadily over time as expertise developed.
2. The correlation between IQ and performance was only very slightly positive among individuals with over 5 years of professional experience.

Not surprisingly, Hulin et al. (1990) concluded that innate ability (intelligence as assessed by IQ) is of little importance at high levels of expertise. However, many of the studies included in their analyses were concerned with fairly narrow types of learning, and so their conclusions may not apply to more general forms of learning.

One of the few studies to consider *both* the amount of deliberate practice and innate ability was reported by Horgan and Morgan (1990). Improvement in chess-playing performance was determined mainly by deliberate practice, motivation, and the degree of parental support. However, individual differences in nonverbal intelligence were also of importance, accounting for 12% of the variation in chess-playing performance.

Key Terms

Deliberate practice: systematic practice in which the learner is given informative feedback about his/her performance and has the opportunity to correct his/her errors.

Long-term working memory: this is used by experts to store relevant information in long-term memory and to access it through retrieval cues in **working memory**.

Case Study: *Practice Makes Perfect*

David Garret, once a child prodigy violinist, is now an adult virtuoso with a full concert and recording schedule. How did he get where he is? He started playing violin aged 4 and a year later was being taken from his home in Germany to Holland each weekend to study music. From 7 through 10 years old he was making a 6-hour journey every Thursday evening to practice and learn in northern Germany, with the return journey on Sunday nights, and at 10 he was playing with the Hamburg Philharmonic Orchestra. He was practicing 7 to 8 hours a day. Would his amazing performances be achievable by anyone who put in the same number of hours for the same number of years? What do you think?

Evaluation

+ Prolonged practice is clearly essential for the development of expertise.

+ The most effective form of practice is deliberate practice, and Ericsson and Lehmann (1996) have identified its key features.

– Deliberate practice is typically necessary but *not* sufficient for the development of expertise, especially broadly based expertise. As Sternberg and Ben-Zeev (2001, p. 302) argued, "Is one to believe that anyone could become a Mozart if only he or she put in the time? . . . Or that becoming Einstein is just a matter of deliberate practice?"

– The most important kind of expertise developed by most people consists of work-related skills. Work expertise (based on work performance) correlates +.58 with intelligence for high-complexity jobs (Gottfredson, 1997). Thus, work-related expertise is not determined entirely by deliberate practice.

Chapter Summary

Classical conditioning

- The repeated presentation of a conditioned stimulus shortly before an unconditioned stimulus produces classical conditioning.
- The repeated presentation of the conditioned stimulus on its own after classical conditioning has occurred produces experimental extinction.
- According to the Rescorla–Wagner model, the key feature of classical conditioning is that the conditioned stimulus *predicts* the arrival of the unconditioned stimulus. This accounts for the phenomenon of blocking and makes it clear why the conditioned stimulus must precede the unconditioned stimulus for conditioning to occur.
- According to the ecological perspective, associations are learned more readily between certain conditioned and unconditioned stimuli than others. Research on food-aversion learning supports this approach.

Operant conditioning

- Operant conditioning is produced by following a given response with reward. Extinction occurs when that response is no longer followed by reward.

- The pattern of responding in operant conditioning depends on the precise schedule of reinforcement used. The variable ratio schedule generally produces the fastest rate of responding, and continuous reinforcement the slowest rate.
- Effective operant conditioning can also be produced by positive punishment, negative punishment, and avoidance learning.
- Animals exposed to operant conditioning seem to learn means–end relationships, or what leads to what.
- Skinner assumed that virtually any response can be conditioned in any stimulus situation. This notion of equipotentiality is incorrect. What actually happens is more accurately predicted by the ecological approach.
- Skinner exaggerated the importance of external or environmental factors as influences on behavior and minimized the role of internal factors (e.g., goals).

Observational learning

- As Bandura argued, observational learning is an important method for acquiring new ways of behaving.
- There is evidence suggesting that observational learning is as effective as learning based on actually performing the behavior to be learned.
- The processes involved in observational learning can be much more complex than simply imitating someone else's behavior, including an assessment of the model's intentions.

Implicit learning

- Findings on healthy participants from the artificial grammar learning and serial reaction time tasks have apparently provided evidence for implicit learning. However, most studies fail to satisfy the information and sensitivity criteria.
- Amnesic patients have shown evidence of intact implicit learning but impaired explicit learning. However, we often don't know what information is being used by amnesic patients during implicit learning.
- There is some evidence that explicit learning and implicit learning involve different brain areas, with the prefrontal cortex being more activated during explicit learning. However, the findings are generally inconsistent.
- Most of the evidence is consistent with the notion that there is implicit learning as well as explicit learning on many tasks, with implicit learning often preceding explicit learning.

How do you become an expert?

- Idiot savants have very low IQs but nevertheless possess high levels of expertise on certain specific tasks. However, high intelligence is almost essential for developing the expertise needed to succeed in high-complexity jobs.
- Much of the expert knowledge possessed by top-level chess players is in the form of templates (schematic structures). Chess positions are typically stored in three templates with each template containing information relating to about 10 pieces.
- Grandmasters possess more template-based knowledge than lower-level players. In addition, they are superior strategically (e.g., thinking more moves ahead).
- According to Ericsson and Lehmann (1996), prolonged deliberate practice is all that is needed to develop expert performance. In fact, it is much more likely that deliberate practice is necessary but not sufficient.

Further Reading

- Eysenck, M.W. (2006). *Fundamentals of cognition*. Hove, UK: Psychology Press. Implicit learning (Chapter 13) and expertise (Chapter 25) are discussed in more detail in this textbook.
- French, R.M., & Cleeremans, A. (2002*). Implicit learning and consciousness: An empirical, philosophical and computational consensus in the making*.

Hove, UK: Psychology Press. This edited book contains useful contributions by several of the leading researchers on implicit learning.
- Gray, P. (2006). *Psychology* (5th ed.). New York: Worth. There are very clear accounts of classical and operant conditioning in this textbook.
- Robertson, S.I. (2001). *Problem solving*. Hove, UK: Psychology Press. Chapters 8 and 9 of this book contain good coverage of theory and research on expertise.
- Shanks, D.R. (2004). Implicit learning. In K. Lamberts and R. Goldstone (Eds.), *Handbook of cognition*. London: Sage. David Shanks puts forward a powerful case for being skeptical about the existence of implicit learning in this chapter.
- Staddon, J.E.F., & Cerutti, D.T. (2003). Operant conditioning. *Annual Review of Psychology*, *54*, 115–144. This article provides a reasonably up-to-date account of the modern complexities of research and theory on operant conditioning.

Chapter 8

Contents

Human memory

8

Imagine for a moment what it would be like to have no memory. You wouldn't recognize anyone or anything as familiar. You wouldn't be able to talk, read, or write, because you would have no knowledge of language. You would have a very limited personality, because you would know nothing about the events of your own life, and would therefore have no sense of self. The devastating effects associated with the progressive destruction of the human memory system can be seen in patients suffering from Alzheimer's disease.

There are numerous topics in the area of human memory, and only a few of the most important ones are covered here. We start with the fundamental distinction between short-term and long-term memory that has been influential throughout most of the history of research on human memory. We then move on to a more detailed consideration of current thinking on short-term memory, increasingly regarded as a complex working memory system involving processing and temporary storage of information. Next we address the issue of the number and nature of long-term memory systems that we possess. The other side of remembering is, of course, forgetting, which we discuss after having dealt thoroughly with short-term and long-term memory. Finally, we consider aspects of memory in everyday life. More specifically, we discuss autobiographical memory (the story of our lives) and eyewitness testimony (can we believe what eyewitnesses to a crime say they have seen and heard?). Some of the processes and structures involved in remembering stories and other texts are discussed in Chapter 9.

THE LONG AND THE SHORT OF MEMORY

What does human memory look like? Does it consist of a *single* memory system or does it consist of two or more memory systems? There are no easy answers to these questions. However, we start by arguing that there is an important distinction between the information stored away in our brains for periods of time running into months or years (long-term memory) and information held very briefly in memory (short-term memory).

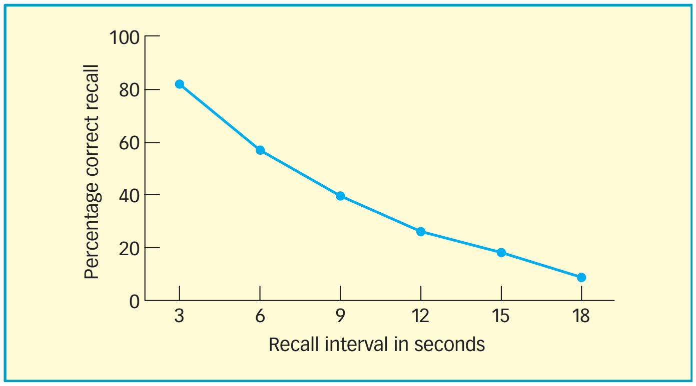
Short-term memory has been assessed in various ways (see Cowan, 2000, for a review). For example, there is **digit span**: people listen to a random series of digits and then try to repeat them back immediately in the correct order. Other span measures are letter span and word span. The maximum number of units (e.g., digits) recalled without error is usually "seven plus or minus two" (Miller, 1956). However, two qualifications need to be put on that finding. First, Miller (1956) argued that the capacity of short-term memory should be assessed in terms of the number of **chunks** (integrated pieces or units of information). For example, "IBM" is *one* chunk for those familiar with the company name International Business Machines but *three* chunks for everyone else. The capacity of short-term memory as assessed by span measures has often been reported as being about seven chunks. However, Simon (1974) found that the span in chunks was less with larger chunks (e.g., eight-word phrases) than with smaller chunks (e.g., one-syllable words).

Second, Cowan (2000) argued that the capacity of short-term memory is only four chunks. According to him, estimates of short-term memory capacity are often inflated because participants' performance depends on rehearsal (i.e., saying the items under one's breath) and on long-term memory as well as on "pure" short-term memory capacity. When these additional factors are eliminated, the capacity of short-term memory is only four chunks. More generally, however, short-term memory capacity (whether four or seven chunks) is hugely less than the essentially unlimited capacity of long-term memory.

Key Terms

Digit span:
the number of random digits that can be repeated back correctly in order after hearing them once; it is used as a measure of short-term memory capacity.

Chunks:
stored units formed from integrating smaller pieces of information.



Forgetting over time in short-term memory. Data from Peterson and Peterson (1959).

Another (very obvious) difference between short-term and long-term memory is in the length of time for which information is remembered. Much information (e.g., our own names; the names of our parents and friends) remains in long-term memory for a lifetime, whereas information in short-term memory is lost rapidly. Peterson and Peterson (1959) studied the duration of short-term memory by using the task of remembering a three-letter stimulus while counting backwards by threes. The ability to remember the three letters in the correct order reduced to only about 50% after 6 seconds and forgetting was almost complete after 18 seconds (see the figure on the left).

What is the most convincing evidence that short-term and long-term memory are distinct? Surprisingly, the strongest evidence comes from brain-damaged patients! Suppose there was only *one* memory system dealing with short-term and long-term memory. If that one and only memory system were damaged, performance would be impaired on *all* memory tasks regardless of whether they involved short-term or long-term memory. In contrast, suppose there are separate short-term and long-term memory systems located in different parts of the brain. It follows that some brain-damaged patients should have impaired long-term memory but intact short-term memory, whereas others should have impaired short-term memory but intact long-term memory. If such findings were obtained, they would form a **double dissociation** (i.e., some patients perform normally on task A but poorly on task B, whereas others perform normally on task B but poorly on task A).

The findings from brain-damaged patients provide evidence for a double dissociation. Patients with **amnesia** have severe problems with long-term memory but have essentially intact short-term memory as assessed by span measures. Indeed, Spiers, Maguire, and Burgess (2001) in a review of 147 amnesic patients concluded that *none* had a significant problem with short-term memory. There are also a few patients having severely impaired short-term memory but intact long-term memory. For example, consider K.F., who suffered brain damage after a motorcycle accident. He had no problems with long-term learning and recall, but his digit span was greatly impaired (Shallice & Warrington, 1970).

Key Terms

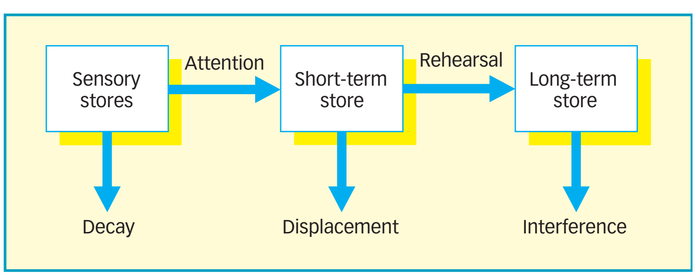
Double dissociation: the finding that some individuals (often brain-damaged) do well on task A and poorly on task B, whereas others show the opposite pattern.

Amnesia: a condition caused by brain damage in which there is substantial impairment of long-term memory; the condition includes both **anterograde amnesia** and **retrograde amnesia**.

MULTI-STORE MODEL

How are short-term and long-term memory related? An influential answer was provided by Atkinson and Shiffrin (1968) in their multi-store model (see the figure below). They assumed that stimulation from the environment is initially received by the sensory stores. These stores are modality-specific, meaning there is a separate one for each sensory modality (e.g., vision; hearing). Information is held briefly in the sensory stores, with some fraction being attended to and processed further within the short-term store. The short-term store itself has very limited capacity. Some information processed in the short-term store is transferred to the long-term store, which has unlimited capacity. Long-term storage of information often depends on rehearsal, with a direct relationship between the amount of rehearsal in the short-term store and the strength of the stored memory trace.

According to Atkinson and Shiffrin (1968), short-term memory is involved *before* long-term memory. However, an increasingly popular view is that short-term memory is only involved *after* long-term memory. According to Ruchkin, Grafman, Cameron, and Berndt (2003, p. 711), "Short-term memory corresponds to activated long-term memory and information is stored in the same systems that initially processed the information." For once, a theoretical controversy can be resolved without discussing experimental findings in detail. The information processed in short-term memory *must* already have made contact with information in long-term memory (Logie, 1999). For example, our ability to engage in verbal rehearsal of



The multi-store model of memory.

visually presented words depends on prior contact with stored information concerning pronunciation. In similar fashion, we can only rehearse "IBM" as a single chunk in short-term memory by using relevant information stored in long-term memory. Thus, access to long-term memory occurs *before* information is processed in short-term memory.

There is another reason why Atkinson and Shiffrin's (1968) assumption that information is processed in short-term memory before reaching long-term memory should be rejected (Marc Brysbaert, personal communication). Atkinson and Shiffrin assumed that information in short-term memory represents "the contents of consciousness," implying that *only* information processed consciously can be stored in long-term memory. However, there is reasonable (if not conclusive) evidence for the existence of learning without conscious awareness of what has been learned (this is known as implicit learning—see Chapter 7). It would seem that implicit learning would be impossible within Atkinson and Shiffrin's (1968) model.

Evaluation

- + The assumption within the model that there are separate short-term and long-term stores has been influential and is approximately correct.
- − As we will see, it is a gross oversimplification to argue that there is a *single* short-term memory store (see section on working memory).
- − It is a gross oversimplification to argue that there is a *single* long-term memory store (see section on types of long-term memory). It seems very doubtful that knowledge that Russell Crowe is a film star, that 2 +2 = 4, that we had muesli for breakfast, and information about how to ride a bicycle are all stored in the same long-term memory store.
- − It doesn't make sense to argue that processing in the short-term store occurs before contact has been made with long-term memory.
- − In contradiction of the assumptions of the multi-store model, learning can probably occur without conscious awareness of what has been learned.

WORKING MEMORY

What is the point of short-term memory in everyday life? Textbook writers sometimes argue that it allows us to remember a telephone number for the few seconds taken to dial it. However, even that function is rapidly becoming obsolete now most people have mobile phones that store all the phone numbers needed on a regular basis.

In 1974, two British psychologists, Alan Baddeley and Graham Hitch, came up with a convincing answer to the above question. They argued that we use short-term memory much of the time when engaged in the performance of complex tasks. You have to carry out various processes to complete the task, but you also have to briefly store information about the outcome of early processes in short-term memory as you move on to later processes. For example, suppose you were given the addition problem 13 + 18 + 24. You would probably add 13 and 18 and keep the answer (i.e., 31) in short-term memory. You would then add 24 to 31 and produce the correct answer of 55. Baddeley and Hitch (1974) used the term **working memory** to refer to a system combining processing and short-term memory functions. According to Baddeley and Logie (1999, p. 28), "Working memory comprises multiple specialized components of cognition that allow humans to comprehend and mentally represent their immediate environment, to retain information about their immediate past experience, to support the acquisition of new knowledge, to solve problems, and to formulate, relate, and act on current goals."

As we saw earlier, Atkinson and Shiffrin (1968) emphasized the importance of verbal rehearsal in short-term memory. Baddeley (e.g., 1986, 2001) accepted that verbal

Key Term

Working memory: a system having the functions of cognitive processing and the temporary storage of information.

rehearsal is important. However, he argued that other kinds of information can also be stored in short-term memory. For example, suppose you are driving along focusing on steering the car, avoiding pedestrians, and keeping a safe distance behind the car in front. In addition, you may be holding some visual and spatial information in short-term memory (e.g., speed limit on the road; width of the road; the distance of the car behind you) to assist you in driving.

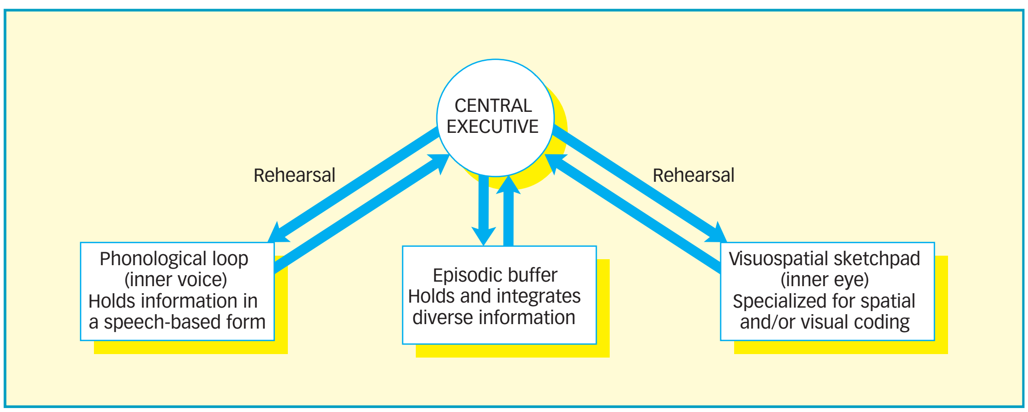
In what follows, we will mainly consider the theoretical approach to working memory put forward by Baddeley and his colleagues. However, other theorists have proposed different approaches to working memory. These other approaches are discussed in a book edited by Miyake and Shah (1999).

WORKING MEMORY MODEL

Baddeley's basic working memory model consisted of three components:

- *Central executive*: This is a limited-capacity processing system resembling attention. It is modality-free, meaning it can process information from any sensory modality (e.g., visual; auditory).
- *Phonological loop*: This is a temporary storage system holding verbal information in a phonological (speech-based) form; it is used for verbal rehearsal.
- *Visuospatial sketchpad*: This is a temporary memory system holding spatial and/or visual information.

The working memory system is hierarchical (see the figure below). The phonological loop and the visuospatial sketchpad are both "slave" systems at the base of the hierarchy. They are slave systems in the sense that they are used by the central executive or attention-like system for various purposes. This figure also shows the episodic buffer, which was only added to the working memory model 25 years after it was first put forward. The episodic buffer is a limited-capacity storage system that integrates information from the phonological loop and the visuospatial sketchpad. Since relatively little is as yet known about the episodic buffer, we won't be discussing it further.



The major components of Baddeley's working memory system. Figure adapted from Baddeley (2001).

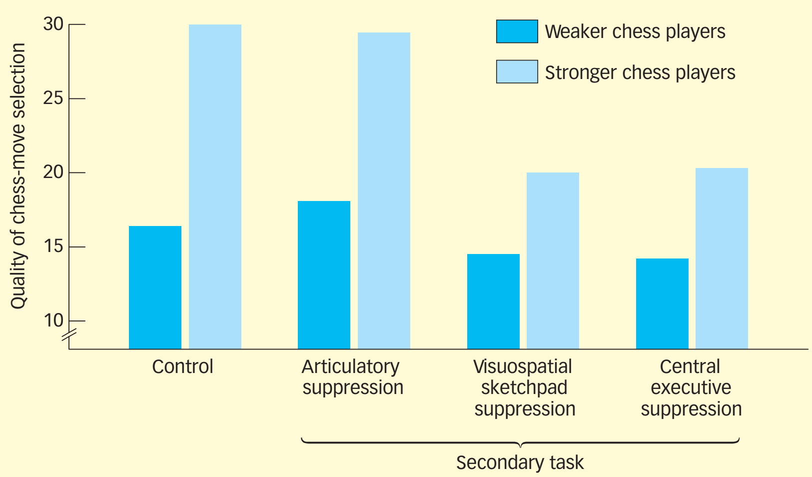
All three components of the basic working memory system have limited capacity. However, each component can function relatively independently of the others. These assumptions permit us to make two crucial predictions concerning whether two tasks can be performed successfully at the same time:

1. If two tasks require the *same* component of working memory, they can't be performed successfully together, because that component's limited capacity will be exceeded.
2. If two tasks require *different* components, it should be possible to perform them as well together as separately.

At this point, let's consider a concrete example of how this works in practice. Robbins et al. (1996) wondered which components of working memory are involved in playing chess. Weaker and stronger players selected continuation moves from various chess positions while performing one of the following secondary tasks at the same time:

- *Random number generation*: This task requires participants to try to produce a random series of digits; it involves the central executive.
- *Pressing keys on a keypad in a clockwise pattern*: This task involves the visuospatial sketchpad.
- *Rapid repetition of the word "see-saw"*: This task involves the phonological loop.
- *Repetitive tapping*: This very simple task places minimal demands on working memory.

Before we discuss the findings, ask yourself which components of working memory you think are involved in playing chess. Chess is a mentally demanding game, and so probably involves the central executive. It also requires considering the layout of the pieces on the board, and so presumably involves the visuospatial sketchpad. The findings were in line with these predictions (see the figure below). The quality of the chess moves selected was reduced by random number generation and by pressing keys in a clockwise fashion, secondary tasks using the central executive and the visuospatial sketchpad, respectively. In contrast, rapid word repetition didn't reduce the quality of chess moves, and so the phonological loop is *not* involved in selecting chess moves. The effects of the various secondary tasks on the quality of the chess moves selected were similar for weaker and stronger players, meaning that both groups used the working memory system similarly when choosing moves. There is more coverage of dual-task performance in Chapter 6.



Effects of secondary tasks on quality of chess-move selection in stronger and weaker players. Adapted from Robbins et al. (1996).

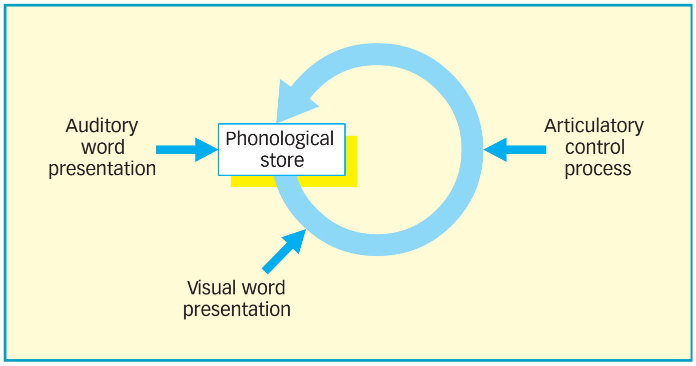
Phonological loop

Why do we need a phonological loop? According to Baddeley, Gathercole, and Papagno (1998), it is very useful when we are learning new words. Supporting evidence was provided by Papagno, Valentine, and Baddeley (1991). They found that the learning of foreign vocabulary was greatly slowed down when participants performed another task using the resources of the phonological loop at the same time.

Most early research on the phonological loop focused on the notion that verbal rehearsal (i.e., saying words over and over to oneself) is of central importance. Evidence for this comes from the **phonological similarity effect**. When a short list of visually presented words has to be recalled immediately in the correct order, recall performance is worse when the words are phonologically similar (i.e., having similar sounds). For example, FEE, HE, KNEE, LEE, ME, and SHE form a list of phonologically similar words, whereas BAY, HOE, IT, ODD, SHY, and UP form a list of phonologically

Key Term

Phonological similarity effect: the finding that immediate recall of word lists in the correct order is impaired when the words sound similar to each other.



Phonological loop system as envisaged by Baddeley (1990).

dissimilar words. Larsen, Baddeley, and Andrade (2000) used those lists, and found ordered recall was 25% worse with the phonologically similar list. This phonological similarity effect occurs because participants use speech-based rehearsal processes within the phonological loop.

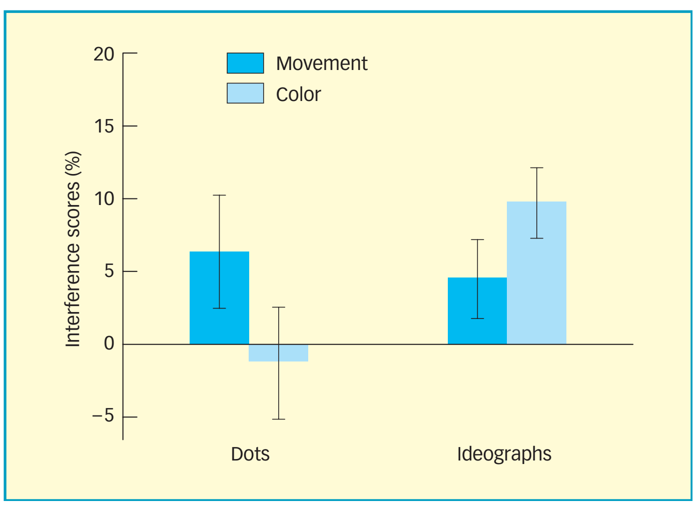
According to Baddeley (1986, 1990), the phonological loop has two main components (see the figure on the left). There is a phonological or speech-based store and an articulatory control process. The phonological store is directly concerned with speech *perception*, whereas the articulatory process is linked to speech *production*. Supporting evidence comes from studies on brain-damaged patients. Some patients have very poor short-term memory for words presented auditorily but have normal speech production (Vallar & Baddeley, 1984). These patients have a damaged phonological store but an intact articulatory control process. Other patients have the opposite pattern of an intact phonological store but a damaged articulatory process preventing verbal rehearsal (Vallar, Di Betta, & Silveri, 1997).

Visuospatial sketchpad

The visuospatial sketchpad is used for the temporary storage and manipulation of visual patterns and spatial movement. It is used in many situations in everyday life (e.g., finding the route when walking; playing computer games). Logie et al. (1989) studied performance on a complex computer game called Space Fortress, which involves maneuvering a space ship around a computer screen. Performance on Space Fortress was initially severely impaired when participants also performed a secondary visuospatial task. However, the adverse effects were greatly reduced after 20 hours of training. Thus, participants made more use of the visuospatial sketchpad early in practice than later on.

A key issue is whether there is a *single* system combining visual and spatial processing or whether there are *separate* visual and spatial systems. Klauer and Zhao (2004) explored this issue. They used two main tasks: one was a spatial task (memory for dot locations) and the other was a visual task (memory for Chinese ideographs). There were also three secondary task conditions: (1) a movement discrimination task (spatial interference); (2) a color discrimination task (visual interference); and (3) a control condition (no secondary task).

What would we predict if there are separate spatial and visual processes? First, the spatial interference task should disrupt performance more on the spatial main task than on the visual main task. Second, the visual interference task should disrupt performance more on the visual main task than on the spatial main task. Both predictions were confirmed (see the figure on the left).



Amount of interference on a spatial task (dots) and a visual task (ideographs) as a function of secondary task (spatial: movement discrimination vs. visual: color discrimination). From Klauer and Zhao (2004). Copyright © American Psychological Association. Reprinted with permission.

Central executive

The central executive, which resembles an attentional system, is the most important and versatile component of the working memory system. Alas, it is also the least well understood. The central executive is used to perform several functions, but it has proved difficult to establish the number (and nature) of these functions. However, Miyake et al. (2000) and Friedman and Miyake (2004) have provided evidence for three major functions of the central executive:

1. *Inhibition + resistance to distractor interference*: This function is used to prevent task-irrelevant stimuli (and responses) from interfering with performance on a current task.

2. *Shifting*: This function is used to shift attention from one task to another. For example, if you were presented with a list of two-digit numbers and had to alternate between adding 3 and subtracting 3 from the numbers (i.e., add 3 to the first number, subtract 3 from the second number, and so on), this would involve the shifting function.
3. *Updating and monitoring*: This function is used when information being held in working memory has to be updated by new information. For example, it would be used if you had to keep track of the last four letters presented in a sequence such as T H G B S K R W F.

Which brain areas are used for central executive functions? According to a review by Collette and Van der Linden (2002), the prefrontal cortex is activated during the performance of most central executive tasks, but other areas including parietal cortex are also sometimes activated. It is unsurprising that the prefrontal cortex should be activated, since it is involved in numerous complex cognitive processes.

TYPES OF LONG-TERM MEMORY

It was argued earlier that the assumption within the multi-store model that there is a single long-term store is highly dubious. Some of the most convincing evidence that there are various long-term memory systems has come from amnesic patients who have serious problems with long-term memory. Before we discuss the relevant experimental evidence, we will have a closer look at amnesia.

AMNESIA

When considering the memory problems of amnesic patients, it is important to distinguish between anterograde and retrograde amnesia. **Anterograde amnesia** involves poor long-term memory for information learned *after* the onset of the amnesia—the findings discussed earlier in the chapter relate to anterograde amnesia. In contrast, **retrograde amnesia** involves poor long-term memory for information learned *before* the onset of amnesia. The extent of retrograde amnesia varies considerably from patient to patient. However, there is generally a *temporal gradient*, with forgetting being greater for memories acquired closer to the onset of the amnesia than those acquired longer ago.

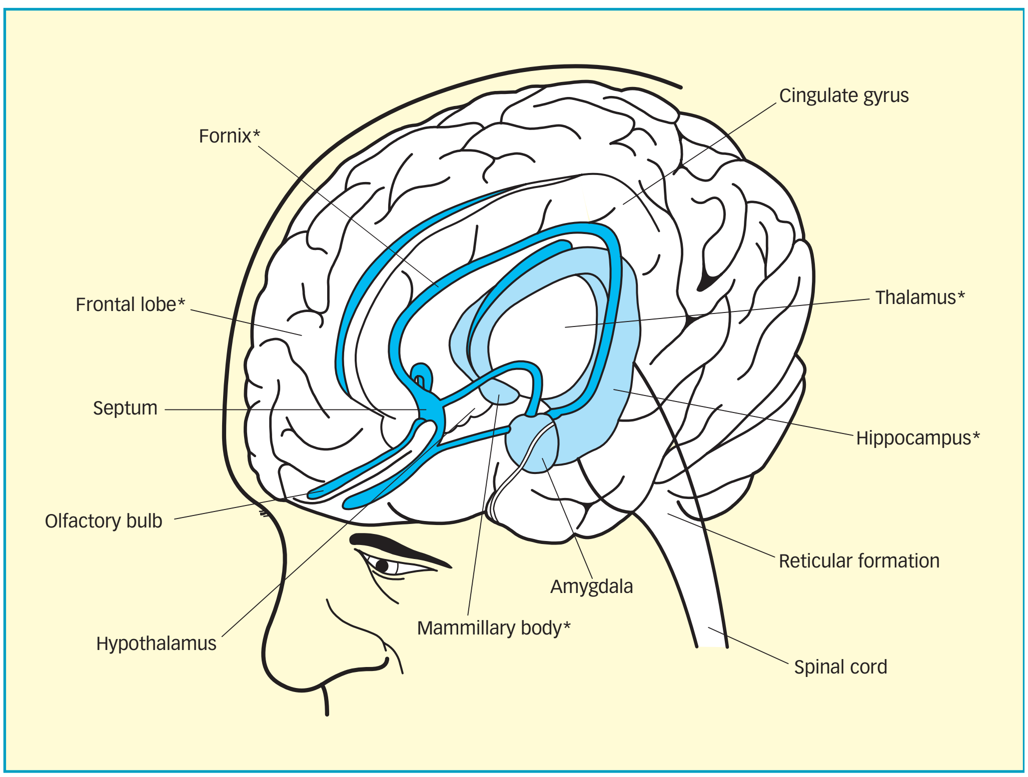
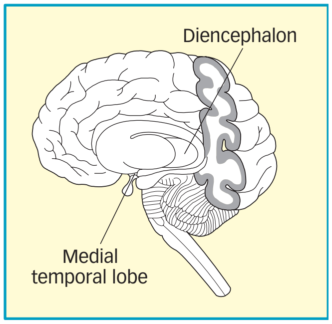


Diagram of the limbic system and related structures. Areas indicated with an asterisk are known to be associated with memory function. From Parkin (2001).

Key Terms

Anterograde amnesia: a reduced ability to remember information acquired *after* the onset of **amnesia**.

Retrograde amnesia: impaired memory for events occurring *before* the onset of **amnesia**.



Amnesic patients vary in the precise brain areas damaged. However, the key structures are in a sub-cortical brain region (the diencephalon) and a cortical region (the medial temporal lobe) (see the figures on the left and on the previous page).

The devastating effects of amnesia can be seen in the case of Clive Wearing, one of the most extreme cases of amnesia ever recorded (see France, 2005, for a detailed discussion). He was a successful 46-year-old musician and Renaissance music scholar. On Tuesday March 26, 1985, he suddenly developed a high temperature. This was as a result of encephalitis (infection of the brain) caused by herpes simplex, the cold-sore virus. As a result of the encephalitis, Clive Wearing can remember practically nothing of his daily activities and can't even remember the names of his children from his first marriage.

When Clive Wearing began to have a vague awareness that there was something terribly wrong with him, he wept almost nonstop for a month. One of his favorite questions was, "What's it like to have one long night lasting . . . how long? It's like being dead."

EXPLICIT VS. IMPLICIT MEMORY

It is perhaps natural to assume that patients with amnesia would have problems with *all* aspects of long-term memory, but that assumption is completely wrong. We can obtain some inkling of what is actually going on by considering a hackneyed anecdote from Edouard Claparède (1873–1940) reported by him in 1911. He studied a female patient (living in what Claparède described, with a total absence of political correctness, as a lunatic asylum!) who suffered from amnesia resulting from chronic alcoholism. She couldn't recognize doctors and nurses she saw virtually every day for several years, and she didn't know what day it was or her own age. One day, Claparède hid a pin in his hand before shaking hands with this patient. The following day she was very sensibly reluctant to shake hands with him but felt very embarrassed because she couldn't explain her reluctance.

What does this anecdote tell us? First, the patient had no conscious recollection of what had happened the previous day. Second, in spite of that, her *behavior* indicated very clearly that she *did* possess some long-term memory of what had happened. Thus, long-term memory can depend less on conscious recollection than we imagine.

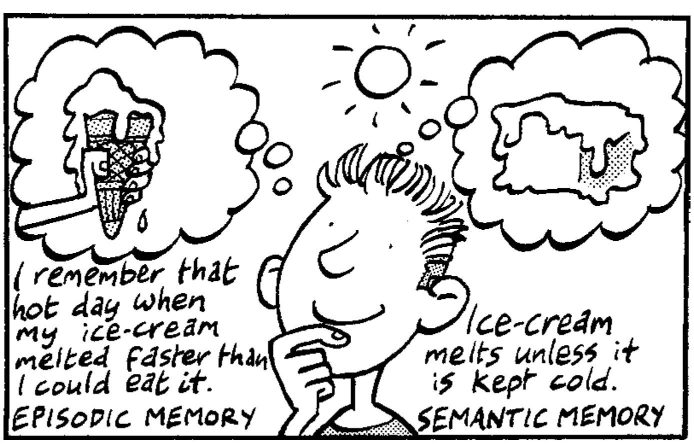
Similar findings to those of Claparède (1911) have been obtained in much more recent studies on amnesic patients (see Parkin, 1996, for a review). For example, patients given a series of piano-playing lessons may have no conscious recollection of having received any previous lessons. However, their piano-playing ability typically improves as rapidly as that of normal controls—thus, their behavior shows that their long-term memory is very good in some ways. Such findings indicate the necessity of distinguishing between explicit and implicit memory: "Explicit memory is revealed when performance on a task requires conscious recollection of previous experiences . . . Implicit memory is revealed when performance on a task is facilitated in the absence of conscious recollection" (Graf & Schacter, 1985, p. 501). Thus, amnesic patients have impaired explicit memory but intact implicit memory.

Key Terms

Episodic memory: a form of long-term memory concerned with personal experiences or episodes that happened in a given place at a specific time; see **semantic memory**.

Semantic memory: a form of long-term memory consisting of general knowledge about the world, language, and so on; see **episodic memory**.

Declarative memory: a form of long-term memory concerned with knowing that something is the case; it includes **episodic memory** and **semantic memory**.



EPISODIC AND SEMANTIC MEMORY

Tulving (1972) distinguished between two long-term memory systems he called episodic memory and semantic memory. **Episodic memory** involves conscious recollection of events or episodes from one's past, generally involving some memory for the relevant time and place. For example, you might remember meeting a friend at a café last Wednesday. In contrast, **semantic memory** is concerned with our general knowledge (e.g., "Paris is the capital of France"). Episodic and semantic memory are both forms of **declarative memory**, which is concerned with knowing that something is the case. They also involve explicit memory.

Do amnesic patients with anterograde amnesia always have impaired episodic and semantic memory for memories acquired after the onset of amnesia? The most definitive answer was provided by Spiers et al. (2001) in their extensive review of 147 cases of amnesia. There was impaired episodic memory in *all* 147 cases, and many (but by no means all) also had poor ability to form new semantic memories. This evidence suggests that episodic memory is more vulnerable to impairment than semantic memory.

Stronger evidence that episodic and semantic may form separate memory systems was reported by Vargha-Khadem et al. (1997). Beth and Jon had suffered brain damage at an early age before they had had the chance to develop semantic memories. Both children had very poor episodic memory for the day's activities, television programs, and telephone conversations. In spite of this, Beth and Jon attended ordinary schools, and their levels of speech and language development, literacy, and factual knowledge (e.g., vocabulary) were within the normal range. Thus, they had very poor episodic memory but virtually intact semantic memory.

If episodic and semantic memory are really separate from each other, *why* do so many amnesics have great problems with both of them? Vargha-Khadem et al. (1997) argued that the brain areas of central importance to episodic memory and semantic memory are very close. Episodic memory depends mainly on the hippocampus, whereas semantic memory depends on its underlying cortices [outer layers]. Thus, brain damage sufficient to impair episodic memory will typically also impair semantic memory.

Finally, we turn to retrograde amnesia (impaired memory for learning occurring before the onset of amnesia). Tulving (2002, p. 13) discussed the case of a patient (KC) whose "retrograde amnesia is highly asymmetrical: he cannot recollect any personally experienced events . . . whereas his semantic knowledge acquired before the critical accident is still reasonably intact. His knowledge of mathematics, history, geography, and other 'school subjects,' as well as his general knowledge of the world is not greatly different from others' at his educational level." The opposite pattern was reported by Yasuda, Watanabe, and Ono (1997). A female amnesic patient had very poor ability to remember public events, cultural items, historical figures, and some items of vocabulary from the time prior to the onset of the amnesia. However, she was reasonably good at remembering personal experiences from episodic memory dating back to the pre-amnesia period.

FORGETTING

Our ability to remember information and the events of our own lives is of tremendous importance. In the absence of memory, we would be in a similar position to a newborn infant, with everything seeming to be completely novel and surprising. It is useful to consider the factors leading to forgetting so we can minimize the amount of information we forget.

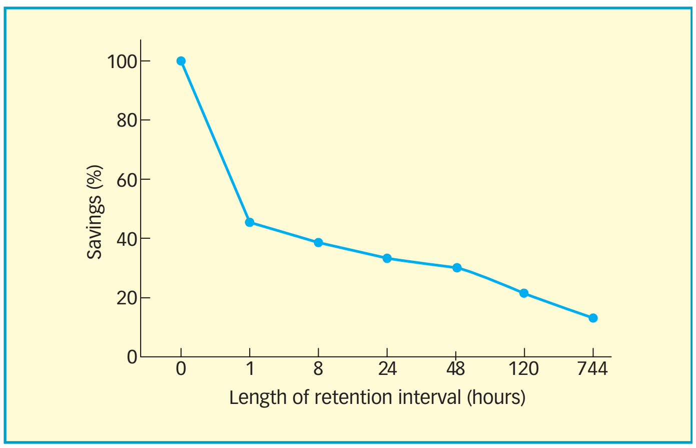
Most people believe their memory is worse than average, which if you think about it can't be true! Evidence that our memories can be poor for important information comes from the study of passwords. Brown, Bracken, Zoccoli, and Douglas (2004) found that 31% of their sample of American students admitted to having forgotten one or more passwords. As Brown et al. (2004, p. 650) pointed out, "We are faced with a continuing dilemma in personal password construction between security and convenience: fool the password hacker and you are likely to fool yourself." They found that 45% of students avoided this dilemma by using their own name in password construction—not the way to have a secure, unguessable password!

In spite of our generally pessimistic views of our own memory ability, most people feel they remember dramatic events (e.g., September 11) in much detail and with great accuracy over long periods of time. The term **flashbulb memories** is used to describe such memories. Brown and Kulik (1977) argued that flashbulb memories are more accurate

Key Term

Flashbulb memories: vivid and detailed memories of dramatic events (e.g., September 11).

What were you doing when you heard about the World Trade Center attacks on September 11 2001? Why do so many people have a vivid memory for this and other extremely emotional and important events?



Forgetting over time as indexed by reduced savings. Data from Ebbinghaus (1885/1913).

Case Study: *What Happened to Susan?*

Zimbardo reports the case of Susan, an 8-year-old who vanished when playing with her friend. Twenty years later, when looking into her own daughter's eyes, this friend started to remember what had happened. She recalled her own father sexually assaulting Susan before killing her. He then threatened his own daughter with the same fate if she revealed what she had seen. As a result of the recovered memory there was a police investigation and the man concerned was convicted and imprisoned. This could be an example of a recovered repressed memory, and the memory would certainly fulfill Freud's concept of very threatening material. However, there is no way of testing whether this memory was truly repressed, or whether it was suppressed until the friend was adult enough to feel safe in remembering it.

and long-lasting than other memories because they activate a special neural mechanism that "prints" the details of dramatic events permanently in the memory system.

Alas, our flashbulb memories are often far less accurate than was predicted by Brown and Kulik (1977) or than we imagine. Pezdek (2003) asked American students the following question: "On September 11, did you see the videotape on television of the first plane striking the first tower?" Seventy-three percent of the students said "Yes," which is incorrect (only videotape of the *second* tower being hit was shown on September 11). Talarico and Rubin (2003) found (surprisingly) that students' memories for the events of September 11 changed as much as their memories for everyday events. However, the students *claimed* that their flashbulb memories were much more vivid than their everyday memories.

Why do we mistakenly think our flashbulb memories are vivid and long-lasting? Winningham, Hyman, and Dinnel (2000) provided an important part of the answer. They studied memory for the unexpected acquittal of O.J. Simpson (a retired American football star) who had been accused of murdering his ex-wife and her friend. They found that people's memories changed considerably in the first few days after hearing about the acquittal but became consistent after that. This version of a dramatic event that is constructed over the first few days afterwards may indeed be long-lasting and vivid. However, it is *not* what we memorized at the time of learning about the event.

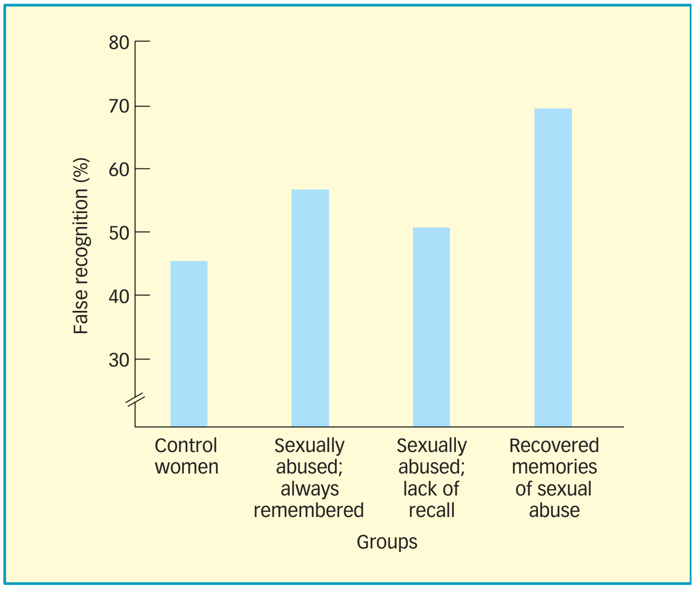
The central issue in forgetting research was identified by the German psychologist Hermann Ebbinghaus (1885/1913). He carried out extensive studies with himself as the only participant (not a practice to be recommended or copied!). His basic approach involved learning a list of nonsense syllables having little or no meaning. He then re-learned the list and assessed forgetting by the savings method (the reduction in the number of trials during re-learning compared to original learning). As can be seen in the figure on the left, forgetting increased over time (this is known as the forgetting curve). Explaining *why* this happens is the goal of much forgetting research.

ARE TRAUMATIC MEMORIES REPRESSED?

The bearded Austrian psychologist Sigmund Freud (1856–1939) put forward one of the most influential theories of forgetting. According to him, very threatening or traumatic memories are often stored in the unconscious and can't gain access to conscious awareness—this phenomenon is known as **repression**. However, Freud sometimes used the concept of repression to refer merely to the inhibition of the capacity for emotional experience (Madison, 1956), with traumatic memories being consciously accessed but drained of their emotional significance.

The whole issue of repression is the subject of current debate. Much of the relevant evidence is based on adult patients claiming to have recovered repressed memories of sexual and/or physical abuse suffered in childhood. There is controversy as to whether these recovered memories are genuine or false.

Andrews et al. (1999) reported evidence supporting the view that many recovered memories are genuine. They obtained detailed information from over 200 patients, and found 41% had supporting evidence for their claims (e.g., someone else had also reported being abused by the alleged perpetrator). In addition, 22% of the patients claimed the trigger for the first recovered memory occurred before therapy started. This is important, because it is often assumed that direct pressure from the therapist influences patients' false memories. For example, Lief and Fetkewicz (1995) studied 40 patients who had admitted their "memories" of childhood abuse were false. In 80% of these cases, the therapist had made direct suggestions that the patient had been the victim of childhood abuse.



False recognition of a word related to those presented in four groups of women (controls; sexually abused, always remembered; sexually abused, lack of recall; and women with recovered memories of sexual abuse). Data from Clancy et al. (2000).

Evidence casting some doubt on recovered memories was reported by Clancy, Schacter, McNally, and Pitman (2000). They used a memory task known to produce false memories: people are given lists of words all related in meaning, and then falsely "recognize" other words related in meaning to those presented. They compared women with recovered memories of childhood abuse with women who believed they had been sexually abused but couldn't recall the abuse, women who had always remembered being abused, and control women. Women reporting recovered memories showed higher levels of false recognition than any of the other groups (see the figure above). As Clancy et al. (2000, p. 30) concluded, "The results are consistent with the hypothesis that women who report recovered memories of sexual abuse are more prone than others to develop certain types of illusory memories."

Key Term

Repression: motivated forgetting of traumatic or other very threatening events.

Proactive interference: disruption of memory by previous learning, often of similar material; see **retroactive interference**.

Evaluation

- \+ There is strong evidence that repressed memories of childhood abuse exist.
- − Some recovered memories have been shown to be false (e.g., Lief & Fetkewicz, 1995).
- − Repression theory is very limited, because most forgetting doesn't relate to traumatic events.

INTERFERENCE THEORY

If any of your female acquaintances are married, you may have found yourself remembering their maiden name rather than their married name. Thus, what used to be their name interferes with or disrupts your ability to recall their current name. The notion that interference is important in forgetting can be traced back at least to the nineteenth century and to a German psychologist called Hugo Münsterberg (1863–1916). Men had pocket watches in those days, and Münsterberg kept his watch in one particular pocket. When he started to keep it in a different pocket (for reasons lost in the mists of time), he found he was often fumbling around in confusion when asked for the time.

After reorganizing the contents of kitchen cupboards, you may find yourself looking for something in its old location, even weeks after everything has been moved. This is an example of interference—memory for the old location is interfering with memory for the new one.

The above anecdote shows the key features of what became known as interference theory. Münsterberg had learned an association between the stimulus, "What's the time, Hugo?," and the response of removing the watch from his pocket. Subsequently the stimulus remained the same, but a different response was now associated with it. This is an example of **proactive interference**, in which previous learning disrupts later learning

Methods of testing for proactive and retroactive interference

Proactive interference

Group	*Learn*	*Learn*	*Test*
Experimental	A–B (e.g. Cat–Tree)	A–C (e.g. Cat–Dirt)	A–C (e.g. Cat–Dirt)
Control	–	A–C (e.g. Cat–Dirt)	A–C (e.g. Cat–Dirt)

Retroactive interference

Group	*Learn*	*Learn*	*Test*
Experimental	A–B (e.g. Cat–Tree)	A–C (e.g. Cat–Dirt)	A–B (e.g. Cat–Tree)
Control	A–B (e.g. Cat–Tree)	–	A–B (e.g. Cat–Tree)

Note: for both proactive and retroactive interference, the experimental group exhibits interference. On the test, only the first word is supplied, and the subjects must provide the second word.

and memory (see the box on the left). There is also **retroactive interference**, in which later learning disrupts memory for earlier learning (see the box on the left). Proactive and retroactive interference are both greatest when two different responses are associated with the same stimulus (e.g., Münsterberg with his watch), intermediate when two similar stimuli are involved, and least with two very different stimuli (Underwood & Postman, 1960).

Numerous laboratory studies have produced large proactive and retroactive interference effects. Many of these studies involved paired-associate learning (e.g., learn "Cat–Tree" and then respond "Tree" when "Cat" is presented on its own). These findings with artificial tasks don't necessarily mean that interference is important in everyday life. However, Isurin and McDonald (2001) argued that retroactive interference explains why people forget some of their first language when acquiring a second language. Bilingual participants fluent in two languages were first presented with various pictures and the corresponding words in Russian or Hebrew. Some were then presented with the same pictures and the corresponding words in the other language. Finally, they were tested for recall of the words in the first language. There was substantial retroactive interference—recall of the first-language words became progressively worse the more learning trials there were with the second-language words.

It has generally been assumed that individuals who find their memory performance disrupted by interference *passively* allow themselves to suffer from interference. However, doesn't it seem likely that you would adopt some *active* strategy to minimize any interference effects? Kane and Engle (2000) explored this issue. They found that intelligent individuals with high attentional capacity were better able to resist proactive interference than less intelligent ones with low attentional capacity.

Evaluation

- (+) Much forgetting inside and outside the laboratory is a result of proactive and retroactive interference.
- (+) As predicted, the amount of interference (proactive or retroactive) is greatest when the same stimulus is paired with two different responses.
- (–) Interference theory tells us little about the internal processes involved in forgetting.
- (–) Interference theory accounts for much forgetting, but doesn't directly explain the precise nature of the forgetting curve.

Key Term

Retroactive interference: disruption of memory by learning of other material during the retention interval; see **proactive interference**.

Encoding specificity principle: the notion that retrieval depends on the overlap between the information available at retrieval and the information within the memory trace.

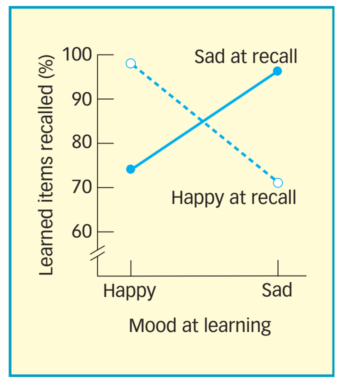
CUE-DEPENDENT FORGETTING

Tulving (e.g., 1979) argued that successful retrieval depends on two kinds of information: (1) the information stored in the memory trace; and (2) the information available at the time of retrieval. We are most likely to remember something when the information available at the time of retrieval *matches* the information in the memory trace. This is known as the **encoding specificity principle**. Tulving also assumed that the memory trace generally contains contextual information (e.g., the learner's mood state; details of the room in which learning occurs) in addition to information about the to-be-remembered material.

What does Tulving's approach tell us about forgetting? In essence, memory performance will be worse (and so forgetting will be greater) when the contextual information present at the time of retrieval *differs* from that stored in memory. This effect (illustrated by **mood-state-dependent memory**) was shown amusingly in the film *City Lights*. Charlie Chaplin saves a drunken millionaire from attempted suicide and is befriended in return. When the millionaire sees Charlie again, he is sober and fails to recognize him. However, when the millionaire becomes drunk again, he treats Charlie like a long-lost friend, and takes him home with him. The next morning, when the millionaire is sober again, he forgets that Charlie is his invited guest, and gets his butler to throw him out.

The film *City Lights* illustrates the concept of mood-state-dependent memory.

Kenealy (1997) obtained good evidence for mood-state-dependent memory. She put people into a happy or sad mood before asking them to look at a map and learn instructions concerning a given route. The next day they were again put into a happy or sad mood, and told to recall as much information as possible. There was much more forgetting when the mood at learning and at test was different than when it was the same (see the figure on the right).



Free recall as a function of mood state (happy or sad) at learning and at recall. Based on data in Kenealy (1997).

We all know that recognition memory is better than recall. For example, we may be unable to recall the name of an acquaintance, but if someone mentions their name we recognize it instantly. Why is recognition memory generally better than recall? According to Tulving, the match between the information in the memory trace and that available on the memory test is typically greater on a recognition test (the whole item is presented). Intriguingly, however, Tulving's theory predicts that recall *can* be better than recognition memory provided that the information in the recall cue matches the stored information better than the information in the recognition cue.

The above prediction was tested by Muter (1978). Participants were presented with names of people (e.g., DOYLE) and told to circle those they "recognized as a person who was famous before 1950." They were then given recall cues in the following form (e.g., author of the Sherlock Holmes stories: Sir Arthur Conan ______). You may well have found the recall item easier than the recognition one because so much more information was supplied. What Muter (1978) discovered was that participants recognized only 29% of the names but recalled 42% of them.

Evaluation

- + What we remember or forget depends in part on the extent to which information in the memory trace matches that available at the time of retrieval.
- + There is reasonable evidence for mood-state-dependent memory.
- + There is evidence (e.g., Muter, 1978) for the surprising prediction that recall can be better than recognition memory.
- – Retrieval is often more complex than simply comparing the information in the memory trace with that available on the memory test. For example, you might use a complex strategy to remember what you did 6 days ago.
- – Tulving (1979) assumed that context influenced recall and recognition in the same way. In fact, however, it generally influences recall much more than recognition (Godden & Baddeley, 1975, 1980).

CONSOLIDATION IS THE ANSWER!

The most adequate answer to the question of why the forgetting curve exists is provided by consolidation theory. According to this theory, **consolidation** is a long-lasting process fixing information in long-term memory. The theory's crucial assumption is that recently

Key Terms

Mood-state-dependent memory: the finding that memory is better when the mood state at retrieval is the same as that at learning than it is when the two mood states differ.

Consolidation: a process mostly completed within several hours, but which can last for years, which fixes information in **long-term memory**.

formed memories in an early stage of consolidation are especially vulnerable to interference and forgetting. More specifically, "New memories are clear but fragile and old ones are faded but robust" (Wixted, 2004, p. 265). The initial phase of consolidation lasts for several hours and is centered on the hippocampus.

Support for consolidation theory comes from patients with retrograde amnesia, in which there is impaired memory for events occurring before the onset of the amnesia. Many of these patients have damage to the hippocampus, and so memories formed just before the accident should be most impaired. This pattern has been found in numerous patients with retrograde amnesia (Manns, Hopkins, & Squire, 2003).

The assumption that memories are most vulnerable during the early stages of consolidation has been tested in studies on interference. We saw earlier that retroactive interference can cause forgetting. According to consolidation theory, people should be most susceptible to retroactive interference *early* in the retention interval. There is much experimental support for this prediction (see Wixted, 2004, for a review).

Evaluation

- + Consolidation provides a plausible explanation of *why* the rate of forgetting decreases over time.
- + Consolidation theory successfully predicts that retrograde interference effects will be greater shortly after learning has occurred than they will be later on.
- – Consolidation provides a rather general account, and doesn't explain why retroactive interference is greatest when two different responses are associated with the same stimulus.
- – Consolidation theory has little or nothing to say about the mechanisms underlying cue-dependent forgetting.

Key Term

Ecological validity: the extent to which the findings of laboratory studies are applicable to everyday settings and generalize to other locations, times, and measures.

EVERYDAY MEMORY

As you have read this chapter, you may have wondered whether memory in everyday life works in the same way as memory studied in the laboratory. The key issue here is that of **ecological validity**, which concerns the extent to which laboratory findings generalize (or are applicable) to real life. It is important not to exaggerate the seriousness of this issue. Laboratory studies provide clear and replicable findings under controlled conditions and have contributed much to our understanding of human memory. You might imagine that the way to increase our understanding of everyday memory would be to carry out studies in naturalistic conditions even if such studies lacked experimental control. However, what has actually proved very successful is to carry out laboratory tasks involving memory phenomena of importance in the real world. Two examples of this approach are discussed in the box on the left.

Everyday memory research studies: Two contrasting examples of research into everyday memory

Green (1995) measured cognitive performances such as vigilance, reaction speed, and memory and then asked participants to complete a questionnaire. The memory and other deficits his tests showed up were in those who were on diets—and equivalent to deficits expected after drinking two units of alcohol. Further research confirmed his findings, but only for people dieting to lose weight, not those on diets for medical reasons. And people trying but not succeeding in losing weight had the greatest memory deficits. Green suggests that the cause of these deficits is psychological, a combination of anxiety/stress and the use of mental processing capacity in thinking about food, diet, and weight.

Chan, Ho, and Cheung (1998) investigated memory in women who had at least 6 years of music lessons before the age of 12, and in women with no musical training. None of her participants were professional musicians. She found no difference in visual memory between her two groups, but the women with the music lessons background did much better in memory tests involving words—possibly because their brains had the extra sound-processing experience. She suggests there might be an application of these findings in therapy for patients with language impairments.

AUTOBIOGRAPHICAL MEMORY

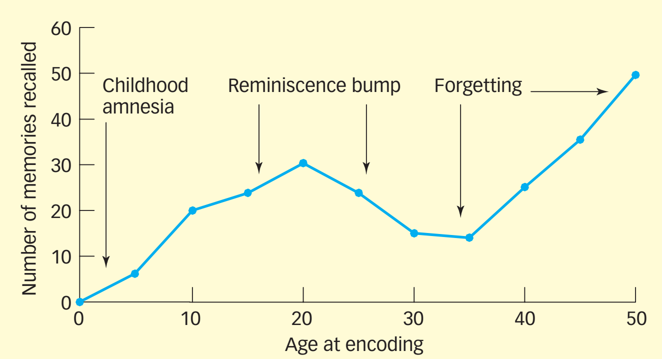
Of all the hundreds of thousands (or even millions) of memories we possess, those relating to our own past, to the experiences we have had, and to the people who have really mattered to us have special importance and significance. This is the territory of autobiographical memory.

If you have read any autobiographies, you probably wondered whether the authors provided an unduly positive view of themselves and their accomplishments. Wilson and Ross (2003, p. 137) reviewed the evidence on autobiographical memories and concluded that, "People's constructions of themselves through time serve the function of creating a coherent—and largely favorable—view of their present selves and circumstances." For example, Karney and Frye (2002) found that spouses often recalled their past contentment as lower than their present level of satisfaction. However, this apparent improvement over time was generally illusory, because spouses mostly underestimated their past contentment.

What do elderly people remember?

Suppose we ask 70-year-olds to recall personal memories triggered by cue words. From which parts of their lives would most of the memories come? Is it really true that they mostly recall distant childhood memories? The short answer is, "No." As can be seen in the figure below, there are three key features when we look at the periods of their life from which 70-year-olds recall more and fewer memories:

- **Infantile amnesia** (also known as childhood amnesia): This is shown by the almost total lack of memories from the first 3 years of life.
- A **reminiscence bump**, consisting of a surprisingly large number of memories coming from the years of adolescence and early adulthood (especially 15 to 25).
- A *retention function* for memories up to 20 years old, with the older memories being less likely to be recalled than more recent ones. This merely reflects the normal course of forgetting and so won't be discussed further.



Idealized representation of the age at which autobiographical memories were formed in elderly people recalling the past. From Conway & Pleydell-Pearce (2000). Copyright © American Psychological Association. Reprinted with permission.

How can we explain infantile amnesia (a phenomenon found in adolescents and young adults as well as the elderly)? According to Freud's (1915/1957) famous (or notorious) account, it occurs through repression (discussed in the forgetting section), with threat-related experiences in early childhood being consigned to the unconscious. Alas, there is practically no support for this theoretical position, and it doesn't explain why *pleasant* early memories can't be recalled.

Howe and Courage (1997) argued that infants can only form autobiographical memories after they have developed a sense of self (they called it "cognitive self") towards the end of the second year of life. The finding that the cognitive self appears shortly before the onset of autobiographical memory fits the theory. Howe, Courage, and Edison (2003) found in infants aged between 15 and 23 months that those showing evidence of a cognitive self had better memory for personal events than infants who did not. When they studied a group of infants from 15 to 23 months, they found that no child showed good performance on a memory test for personal events before achieving self-recognition.

The social-cultural-developmental theory (Fivush & Nelson, 2004) emphasizes other factors involved in infantile amnesia. According to this theory, language and culture both play central roles in the early development of autobiographical memory. Language is important because we use language to communicate our memories, and experiences occurring before children develop language are hard for them to express in language later on. Support for this theory comes from Simcock and Hayne (2002). They asked young children of 3 and 4 to describe their memories for complex play activities that had occurred 12 months earlier. The children *only* used words they had known at the time of the event even though they had acquired hundreds of new words subsequently. Harley and Reese (1999) found there was less infantile amnesia in children whose mothers often discussed the past than in children whose mothers rarely talked about the past.

In sum, it is likely that the onset of autobiographical memory in infants depends on the emergence of the self. Its subsequent expression is heavily influenced by social factors,

Key Terms

Infantile amnesia: the inability of adults to recall autobiographical memories from early childhood.

Reminiscence bump: the tendency of older people to recall a disproportionate number of autobiographical memories from the years of adolescence and early adulthood.

cultural factors, and infants' development of language (see Baddeley, Anderson, & Eysenck, 2009).

How can we explain the reminiscence bump? According to Rubin, Rahhal, and Poon (1998), the key factors are novelty and stability. Early adulthood is a time of life in which many important novel events occur. Novel events have the advantage in memory that there is a relative lack of proactive interference (interference from previous similar events). A sense of adult identity develops in early childhood, and this heralds a period of relative stability. If the structure of autobiographical memory established in early adulthood remains fairly stable throughout the rest of one's life, it provides an effective way of cuing memories of early adulthood.

Pillemer, Goldsmith, Panter, and White (1988) showed that novelty is important. When they asked middle-aged people to recall four memories from their first year at college over 20 years previously, 41% of their autobiographical memories came from the first month of the course.

Theoretical views

According to Conway and Pleydell-Pearce (2000), autobiographical memory depends on an autobiographical memory base and the working self. The autobiographical memory base contains personal information at three levels of specificity: lifetime periods (e.g., time at high school; time spent living with someone); general events (e.g., a holiday in the United States); and event-specific knowledge (e.g., a specific occurrence on a holiday). The working self is concerned with the self, what it may become in future, and with the individual's current goals. The goals of the working self influence the memories stored within the autobiographical knowledge base and also help to determine which autobiographical memories we recall. As a result of the role played by the working self, "Autobiographical memories are primarily records of success or failure in goal attainment" (Conway & Pleydell-Pearce, 2000, p. 266).

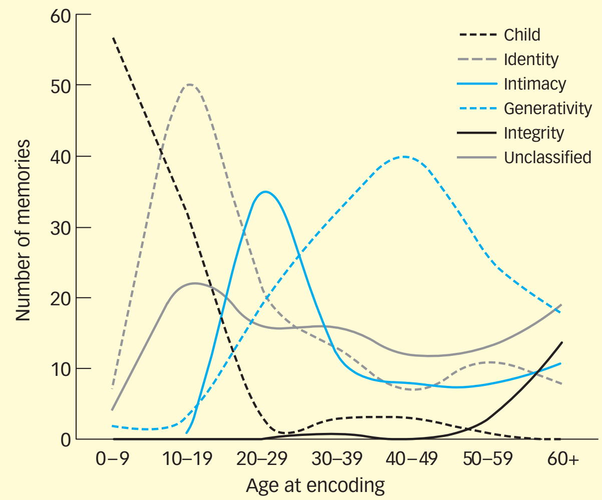
Convincing evidence that our major goals influence our autobiographical memories was reported by Woike, Gershkovich, Piorkowski, and Polo (1999). They identified two types of personality: (1) agentic personality type, with an emphasis on independence, achievement, and personal power; and (2) communal personality type, with an emphasis on interdependence and similarity to others. Participants wrote about a positive or negative autobiographical memory. When the experience was positive, nearly all the communal participants recalled communal memories (e.g., involving love or friendship) whereas two-thirds of the agentic participants recalled agentic memories (e.g., involving success). With negative experiences, nearly all communal participants recalled communal memories (e.g., involving betrayal of trust) whereas half of the agentic individuals recalled agentic memories (e.g., involving failure).

The goals important to us change somewhat during the course of our lives. According to Erikson (e.g., 1968), we go through several psychosocial stages of development, and the goals and problems at each stage differ. More specifically, we go through the following psychosocial stages:

1. Childhood: wanting to be nurtured; having fun.
2. Identity/identity confusion: relating to peers and friends.
3. Intimacy/isolation: trying to achieve mutual intimacy.
4. Generativity/stagnation: being concerned/unconcerned about others' welfare.
5. Integrity/despair: focus on meaningful/meaningless nature of life.

Conway and Holmes (2004) asked older adults to recall up to three memories from each decade of their lives. The memories recalled were assigned to the psychosocial stages identified above. As predicted, autobiographical memories from each decade tended to reflect the psychosocial goals and problems that would have been dominant at that time (see the figure on the following page).

Evidence for the notion that there are three types of autobiographical knowledge was discussed by Conway and Rubin (1993). Brain-damaged patients with retrograde amnesia (widespread forgetting of events preceding the brain injury) often cannot recall



Numbers of memories recalled by older adults classified by psychosocial stage and by the age at which the event occurred. From Conway and Holmes (2004). Copyright © 2004 Blackwell Publishing. Reprinted with permission.

event-specific memories. However, they can recall general events and knowledge of lifetime periods. Other patients can recall only information about lifetime periods. Thus, event-specific knowledge is most vulnerable to loss or disruption, and knowledge of lifetime periods is least vulnerable.

Evaluation

- (+) The notion that autobiographical memory has a hierarchical structure is plausible and in line with the evidence.
- (+) There is support for the notion that the self and its goals are important in autobiographical memory.
- (–) Our understanding of the role of the working self is based mainly on consciously accessible information. However, some aspects of the working self (e.g., some of its goals) may not be consciously accessible.
- (–) As yet, we know little of how the working self interacts with the autobiographical knowledge base to produce recall of specific autobiographical memories.

EYEWITNESS TESTIMONY

You are a juror in a murder case. You are undecided whether the defendant is the murderer because the evidence is unclear. However, one piece of evidence seems very direct and revealing. An eyewitness was present at the time of the murder, and he has identified the defendant as the murderer in an identification line-up. When you see the eyewitness being questioned in court, he seems very confident he has correctly identified the murderer. As a result, you and your fellow jurors decide the defendant is guilty of murder, and he is sentenced to life imprisonment.

Most jurors are strongly influenced by eyewitness testimony, especially when they are very confident they have identified the culprit. Many psychologists are concerned about our tendency to accept without question what eyewitnesses report. The advent of DNA tests means we can often establish whether the person convicted of a crime was actually responsible. In the United States, more than 100 convicted people have been

Eyewitness testimony has been found by psychologists to be extremely unreliable, yet jurors tend to find such testimony highly believable.

shown to be innocent by DNA tests, and more than 75% of them were found guilty on the basis of mistaken eyewitness identification. The 100th innocent person freed after DNA testing was Larry Mayes of Indiana. He was convicted of raping a cashier at a filling station after she identified him in court. Thomas Vanes, the lawyer who prosecuted Mayes, believed at the time of the trial that Mayes was guilty. However, the DNA evidence led him to conclude that, "He [Mayes] was right, and I was wrong."

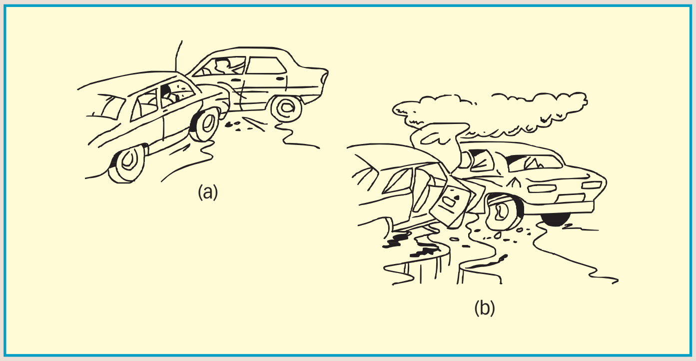
Findings

Why do you think eyewitness testimony is often inaccurate? The most obvious explanation is that eyewitnesses often fail to pay sufficient attention to the crime and to the criminal(s). After all, they were pursuing their own goals when unexpectedly a crime took place close to them. However, Elizabeth Loftus and John Palmer argued that what happens *after* an eyewitness has observed a crime is also very important. More specifically, they claimed that eyewitness memories are fragile and can surprisingly easily be distorted by subsequent questioning (often referred to as post-event information).

Key Study

Loftus and Palmer (1974): Leading questions

Loftus and Palmer (1974) obtained support for their point of view in a study in which people were shown a film of a multiple-car accident. After viewing the film, participants described what had happened, and then answered specific questions. Some were asked, "About how fast were the cars going when they hit each other?," whereas for others the verb "hit" was substituted for "smashed into." Control participants were not asked about car speed. The estimated speed was affected by the verb used in the question, averaging 41 mph when the verb "smashed" was used versus 34 mph when "hit" was used.



One week later, all participants were asked, "Did you see any broken glass?" There wasn't actually any broken glass in the accident, but 32% of those previously asked about speed using the verb "smashed" said they had seen broken glass. In contrast, only 14% of those asked using the verb "hit" said they had seen broken glass, and the figure was 12% for the control participants. Thus, our memory for events is so fragile that it can be distorted by changing *one* word in *one* question!

Discussion points

1. How confident can we be that such laboratory-based findings resemble what would be found in the real world?
2. What are some of the practical implications of this research?

KEY STUDY EVALUATION

Methodologically, this study was well controlled, although, as is common, students were used as participants and it could be argued that students are not necessarily representative of the general population. However, the experiment lacks ecological validity, in that the participants were not real-life witnesses, and it could be said that the emotional effects of being a real-life witness could affect recall. On the one hand film clips may not contain as much information as you would get in real life, but on the other hand the participants knew that something interesting was being shown to them and therefore they were paying full attention to it. In real life, eyewitnesses are typically taken by surprise and often fail to pay close attention to the event or incident, therefore this research lacks mundane realism. The study has real-life applications, particularly in respect of the credence given to eyewitness testimony in court, and the use of taped interviews in police stations.

How concerned do we need to be about the distorting effects of post-event information? Such distorting effects may be less damaging than might be imagined. There is often much more memory distortion for peripheral or minor details (e.g., presence of broken glass) than there is for central details (e.g., features of the criminal) (Heath & Erickson, 1998).

There has been much research on **weapon focus**. This is a phenomenon in which the eyewitness attends so closely to the criminal's weapon that he/she fails to recall details about the criminal and the environment. For example, Loftus, Loftus, and Messo (1987) asked participants to watch one of two sequences:

1. A person pointing a gun at a cashier and receiving some cash.
2. A person holding a cheque to the cashier and receiving some cash.

Key Term

Weapon focus: the finding that eyewitnesses pay so much attention to a weapon that they tend to ignore other details.

Weapon focus is the phenomenon in which eyewitnesses are so distracted by the weapon used in a crime that they will fail to recall other details of the event.

Eyewitnesses looked more at the gun than they did at the cheque. As a result, memory for details unrelated to the gun/cheque was poorer in the weapon condition.

Pickel (1999) argued that a weapon may attract attention either because it poses a threat or because it is unexpected in the context in which it is seen. Pickel produced four videos involving a man approaching a woman while holding a handgun to evaluate these explanations:

1. Low threat; expected: gun barrel pointed at the ground; setting was a shooting range.
2. Low threat; unexpected: gun barrel pointed at the ground; setting was a baseball field.
3. High threat; expected: gun pointed at the woman who shrank back in fear; setting was a shooting range.
4. High threat; unexpected: gun pointed at the woman who shrank back in fear; setting was a baseball field.

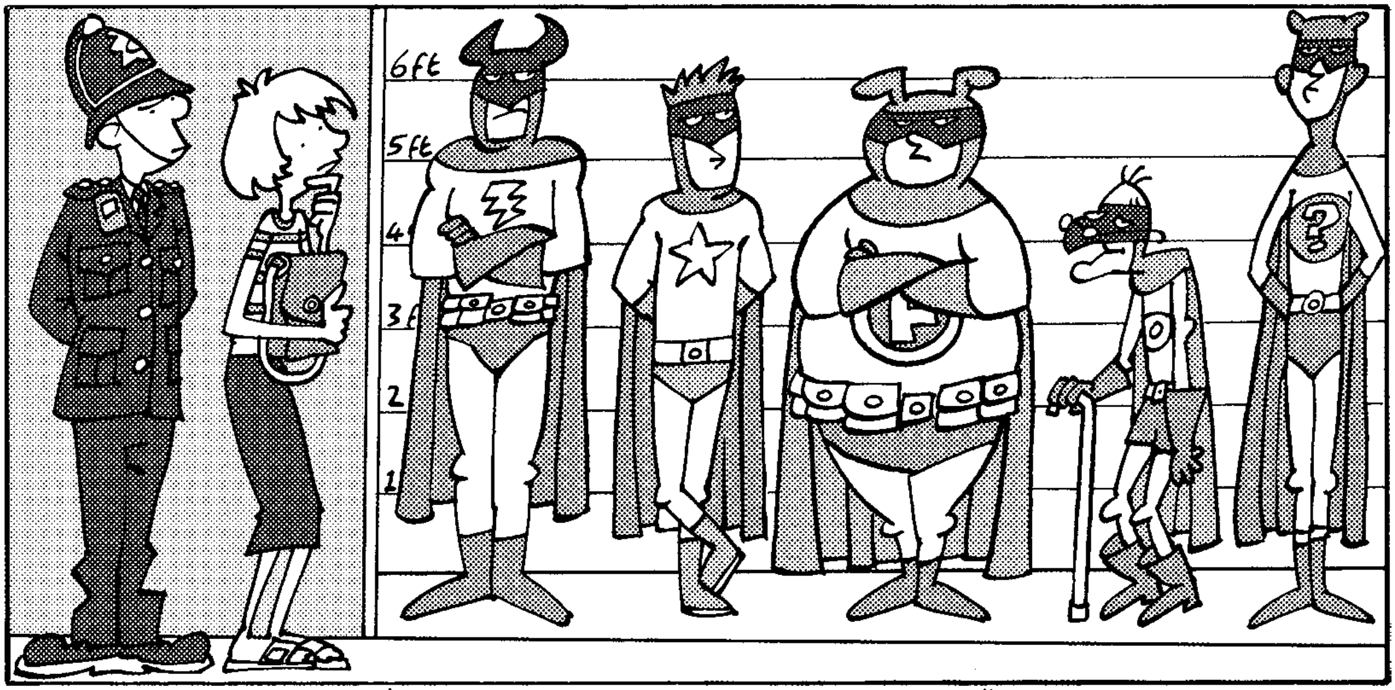
Eyewitnesses' descriptions of the man with the gun were much better when the gun was seen in a setting in which guns are expected (a shooting range) than in a setting in which they are unexpected (a baseball field). However, the level of threat had no influence at all on how much eyewitnesses could remember. Thus, it seems that the weapon focus effect may occur because the presence of a weapon is unexpected rather than because it is threatening.

It seems reasonable to assume that eyewitnesses who are confident they have correctly identified the culprit are more likely to be accurate than those lacking confidence. However, Kassin, Tubb, Hosch, and Memon (2001) found that over 80% of experts in eyewitness testimony agreed that an eyewitness's confidence is *not* a good predictor of his/her identification accuracy. Sporer, Penrod, Read, and Cutler (1995) combined the findings from numerous studies into a meta-analysis. They distinguished between choosers (eyewitnesses making a positive identification) and nonchoosers (those not making a positive identification). There was practically no correlation between confidence and accuracy among nonchoosers, but the average correlation was +.41 among choosers. This indicates that confident choosers were somewhat more likely than nonconfident choosers to make an accurate identification.

Perfect and Hollins (1996) found that participants' confidence didn't predict the accuracy of their memory for a film about a kidnap. They argued that this happens because eyewitnesses don't know whether their ability to remember details of a witnessed event is better or worse than that of other people. However, participants' confidence did predict the accuracy of their performance on general-knowledge questions. Presumably this happened because they knew whether their general knowledge was relatively good or bad compared to other people.

Most eyewitness research is carried out under laboratory conditions. How much confidence can we have that the memory errors made by eyewitnesses in the laboratory would be found in real-world settings? Reassuring evidence was provided by Ihlebaek, Løve, Eilertsen, and Magnussen (2003). They used a staged robbery involving two armed robbers. In the live condition, the eyewitnesses were ordered repeatedly to "Stay down." A video taken during the live condition was presented to eyewitnesses in the video condition. Participants in both conditions exaggerated the duration of the event, and the patterns of memory performance (i.e., what was well and poorly remembered) were similar. However, eyewitnesses in the video condition recalled more information. They estimated the robbers' age, height, and weight more closely, and identified the robbers' weapons more accurately. Thus, the inaccuracies and distortions in eyewitness memory obtained under laboratory conditions *underestimate* eyewitnesses' memory deficiencies for real-life events.

The performance of eyewitnesses when trying to select the suspect from an identification line-up is very fallible. In 300 real line-ups organized by the London Metropolitan Police, Valentine, Pickering, and Darling (2003) found that 40% of witnesses identified the suspect, 20% identified a nonsuspect, and 40% failed to make an identification.



"Well I know he was wearing tights."

What can be done to improve eyewitnesses' identification performance? It has often been argued that warning eyewitnesses that the culprit may not be present in the line-up reduces the chances of mistaken identification. Support for this argument was reported by Steblay (1997), who combined the findings from several studies. Warnings reduced mistaken identification rates in culprit-absent line-ups by 42% while reducing accurate identification rates in culprit-present line-ups by only 2%.

Line-ups are generally simultaneous, meaning the eyewitness is presented with everyone in the line-up at the same time. An alternative is to have sequential line-ups in which the eyewitness sees only one person at a time. Steblay, Dysart, Fulero, and Lindsay (2001) considered 25 relevant studies. Sequential line-ups reduced the chances of mistaken identification when the culprit was absent by almost 50%. However, sequential line-ups also produced a significant reduction in accurate identification rates when the culprit was present. What happens is that eyewitnesses adopt a more *stringent* criterion for identification with sequential than with simultaneous line-ups.

Evaluation

- + Important phenomena have been identified (e.g., distorting effects of post-event information; weapon focus effect; poor relationship between eyewitness confidence and accuracy).
- + Ways of improving the identification performance of eyewitnesses (e.g., warning that the culprit may not be present; sequential rather than simultaneous line-ups) have been discovered.
- − Post-event information may not distort memory for important information as much as for trivial information (Heath & Erickson, 1998).
- − Research on eyewitness identification has practical value but has been relatively uninfluenced by theoretical ideas.

Chapter Summary

The long and the short of memory

- Short-term memory has a capacity of between 4 and 7 chunks of information, and information in short-term memory is held for up to about 18 seconds.
- Some brain-damaged patients have intact short-term memory but impaired long-term memory, and others have the opposite pattern.
- It was assumed incorrectly within the multi-store model that there is only a single short-term store and a single long-term store.
- Baddeley's basic working memory model consists of three components: central executive; phonological loop; and visuospatial sketchpad. The sketchpad seems to consist of fairly separate components specialized for visual and for spatial processing.

Working memory

- Working memory is used when we need to combine processing and short-storage functions.
- The basic working memory model of Baddeley and Hitch consists of a central executive, a phonological loop, and a visuospatial sketchpad.
- The phonological loop has a phonological store and an articulatory control process.
- The visuospatial sketchpad has somewhat separate visual and spatial sub-systems.
- The central executive is attention-like. It is used for various functions, probably including inhibition, shifting, and updating.

Types of long-term memory

- Amnesic patients have problems with explicit memory (involving conscious recollection) but not with implicit memory (not involving conscious recollection).
- All amnesic patients have impaired ability to form new episodic memories. However, impairments of the ability to acquire new semantic memories (general knowledge) are less widespread.

Forgetting

- Numerous adults claim to have recovered repressed memories of sexual and/or physical abuse suffered in childhood. However, there is much controversy concerning the genuineness of these claims.
- Much forgetting is a result of retroactive interference (later learning disrupting memory for earlier learning) and of proactive interference (previous learning disrupting later learning and memory).
- According to the encoding specificity principle, we are most likely to remember something when the information available at the time of retrieval *matches* the information stored in long-term memory. This helps to explain mood-state-dependent memory and the typical superiority of recognition over recall.
- According to consolidation theory, recently formed memories at an early stage of consolidation are especially vulnerable to interference and forgetting. This explains why the rate of forgetting is most rapid shortly after learning.

Everyday memory

- When elderly people recall personal memories to cues, a disproportionate number come from the years of adolescence and early adulthood. This occurs in part because this is a period of life characterized by memorable novel experiences.
- The autobiographical memory base contains personal information about lifetime periods, general events, and event-specific knowledge.
- Our autobiographical memories are influenced by our major goals.
- Many of the inaccuracies of eyewitness testimony are a result of misleading post-event information and others may be because of weapon focus.
- Eyewitnesses' confidence in the accuracy of their memory often fails to predict the actual accuracy.
- Fewer errors are made on identification parades when eyewitnesses are warned that the culprit may not be present, or the line-up is sequential rather than simultaneous.

Further Reading

- Baddeley, A.D., Eysenck, M.W., & Anderson, M.C. (2009). *Memory*. Hove, UK: Psychology Press.
- Emilien, G., Durlach, C., Antoniadis, E., van der Linden, M., & Maloteaux, J.-M. (2004). *Memory: Neuropsychological, imaging, and psychopharmacological perspectives*. Hove, UK: Psychology Press. The first chapter of this book provides a useful overview of memory research.
- Eysenck, M.W. (2006). *Fundamentals of human cognition*. Hove, UK: Psychology Press. The topics discussed in this chapter are dealt with at greater length in this textbook (Chapters 11–16).
- Loftus, E.F. (2004). Memories of things unseen. *Current Directions in Psychological Science*, *13*, 145–147. Elizabeth Loftus considers ways in which our memories can be distorted.

chapter 9

Contents

Thinking: Problem solving and decision making

9

The challenges we face in our everyday lives require us to engage in thinking. In general terms, the more effective our thinking is, the more successfully we are likely to lead our lives. Thinking takes many forms. However, two of the most important forms are problem solving and decision making. In problem solving, we move from recognizing that there is a problem to finding some strategy to produce the required solution. In decision making, we are presented with various options or possibilities and try to select the one with the best consequences for us. These two forms of thinking are the focus of this chapter.

FINDING THE SOLUTION

Life presents us with numerous problems to solve. These problems come in many different shapes and sizes. Some problems are fairly trivial and short (e.g., "How can I get to Cambridge cheaply?"), but others are important and long term (e.g., "How am I going to pass my psychology exam?"). What, if anything, do all attempts at problem solving have in common?

According to Mayer (1990, p. 284), problem solving is "cognitive processing directed at transforming a given situation into a goal situation when no obvious method of solution is available to the problem solver." This definition suggests there are three major aspects to problem solving:

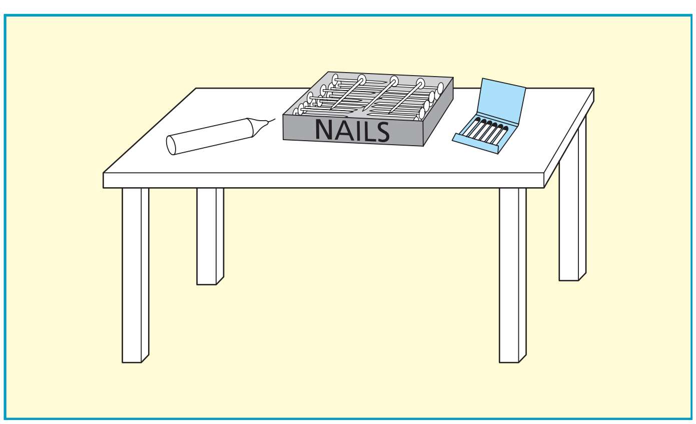
1. It is purposeful in the sense of being goal directed.
2. It requires the use of cognitive processes rather than automatic ones.
3. A problem only exists when someone lacks the relevant knowledge to produce an immediate solution.

Sternberg (2003) argued that there are seven steps in the problem-solving cycle:

1. Problem identification: realizing there is a problem.
2. Problem definition and representation: clarifying the nature of the problem.
3. Strategy formulation: deciding how to tackle the problem.
4. Organization of information: assembling information needed to solve the problem.
5. Resource allocation: deciding which parts of the problem require the greatest allocation of resources.
6. Monitoring: checking progress towards problem solution.
7. Evaluation: assessing whether the proposed solution to the problem is adequate.

Escaping from, or reaching the middle of, a maze is an example of a well-defined problem. It is clear when a solution is reached.

How to retrieve your car keys from a locked car is an ill-defined problem. It can be very hard to identify the best solution.



The objects presented to participants in the candle problem.

There are major differences among problems. Some problems are well-defined whereas others are ill-defined. **Well-defined problems** are ones in which all aspects of the problem are clearly specified, including the range of possible moves or strategies and the goal or solution. Mazes are well-defined problems in which reaching the center is the goal. In contrast, **ill-defined problems** are under-specified. Suppose you have locked your keys inside your car, and want to get into it without causing any damage. However, you have very urgent business to attend to elsewhere, and there is no one around to help you. In such circumstances, it may be difficult to identify the best solution to the problem.

Most everyday problems are ill-defined, but psychologists focus mainly on well-defined problems. Why is this? One important reason is that well-defined problems have a best strategy for their solution. As a result, we can clearly identify the errors and deficiencies in the strategies adopted by human problem solvers.

There is another difference between laboratory and everyday problems. Laboratory studies generally focus on knowledge-lean problems in which the information required to solve the problems is contained in the initial problem statement. In contrast, everyday life often presents us with knowledge-rich problems, which can only be solved if we have a considerable amount of relevant specific knowledge.

HOW USEFUL IS PAST EXPERIENCE?

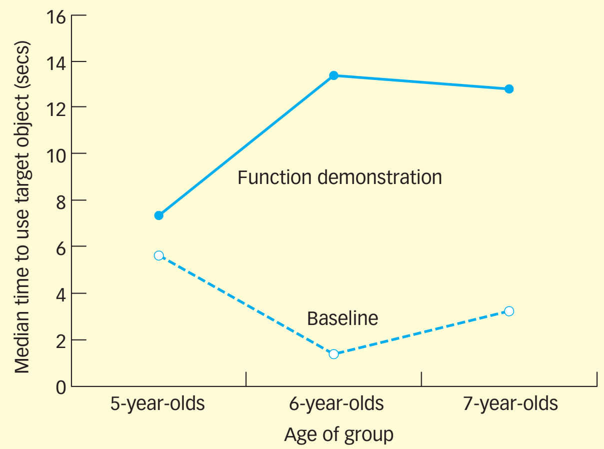
Common sense tells us that our ability to solve a problem is much better if we have relevant past experience with similar problems. Indeed, the crucial reason why adults can solve most problems much faster than children is because of their enormous relevant past experience.

Is past experience *always* useful? The answer is, "No!" For example, Duncker (1945) obtained evidence of **functional fixedness**. This is a phenomenon in which we fail to solve a problem because we assume from past experience that any given object only has a limited number of uses. Duncker gave participants a candle, a box of nails, and several other objects (see the figure below). Their task was to attach the candle to a wall by a table so it didn't drip onto the table. Most participants tried to nail the candle directly to the wall or to glue it to the wall by melting it. Only a few came up with the correct answer, using the inside of the nail-box as a candle holder and then nailing it to the wall.

Duncker (1945) argued that his participants "fixated" on the box's function as a container rather than as a platform. This view was supported by an additional finding. More correct solutions were produced when the nail-box was empty (rather than full) at the start of the experiment. When the nail-box was empty, it looked less like a container.

It is generally assumed that functional fixedness occurs because problem solvers rely too much on their past knowledge and experience. If so, older children might show more functional fixedness than younger children, as was shown by Defeyter and German (2003). Children aged between 5 and 7 removed an object from a transparent tube. This could only be done by using a long stick presented along with several other objects. The main function of this stick (to make light or to make music in different conditions) was demonstrated to some of the children before being given the task.

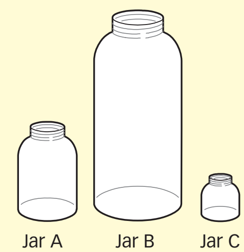
What did Defeyter and German (2003) find? When the stick's main function had not been shown to the children, there were no differences among them in the time taken to select the stick to free the object from the tube (see the figure on the right). However, when its main function had been shown (and so there was a possibility of functional fixedness), the older children took significantly longer than the youngest ones to use the stick. The key finding was that the youngest children (with their limited past experience and knowledge) showed no evidence of functional fixedness.



Median time (in seconds) to select the stick as a function of age and of whether its main function had been shown (function demonstration) or not (baseline). From Defeyter and German (2003). Copyright © 2003 Elsevier. Reproduced with permission.

Past experience doesn't only create problems of functional fixedness. It can also lead us to persevere with problem-solving strategies that are no longer appropriate. Luchins (1942) and Luchins and Luchins (1959) presented water-jar problems involving three water jars of varying capacity. Participants imagined pouring water from one jar to another to finish up with a specified amount of water in one of the jars (see the figure on the right).

The striking findings obtained by Luchins can be illustrated by considering one of his studies in detail. One problem was as follows: Jar A can hold 28 quarts of water, Jar B 76 quarts, and Jar C 3 quarts. The task is to end up with exactly 25 quarts in one of the jars. The solution is not difficult: Jar A is filled and then Jar C is filled from it, leaving 25 quarts in Jar A. Unsurprisingly, 95% of participants who had previously been given similar problems solved it. Other participants were trained on a series of problems all of which had the same complex three-jar solution. Of these participants, only 36% managed to solve this extremely simple problem! The previous problems had created a mental set or "mechanized state of mind" (Luchins, 1942, p. 15) preventing participants from seeing the obvious.



An example of one of the water-jar problems used by Luchins (1942) and Luchins and Luchins (1959); Jar A holds 28 quarts, Jar B holds 76 quarts, and Jar C holds 3 quarts.

Positive transfer

So far we have been discussing **negative transfer**, meaning interfering effects of previous experience on a current problem. In the real world, however, the effects of past experience on problem solving are predominantly positive. The term **positive transfer** describes that state of affairs. Positive transfer is of great practical importance (honestly!). For example, nearly everyone involved in education firmly believes that what students learn at school or university facilitates learning later in life. Thus, it is assumed there is substantial positive transfer from the classroom or lecture theater to subsequent forms of learning (e.g., work-related skills).

Positive transfer often involves making use of analogies or similarities between the current problem and one or more problems solved in the past. For example, consider a study by Gick and Holyoak (1980). They used Duncker's (1945) radiation problem in which a patient has a malignant tumor and can only be saved by a special kind of ray. However, a ray strong enough to destroy the tumor will also destroy the healthy tissue, and a ray that won't harm healthy tissue will be too weak to destroy the tumor.

What is the answer to the radiation problem? If you haven't found it yet, here is an analogy to help you. A general wants to capture a fortress but the roads leading to

Key Terms

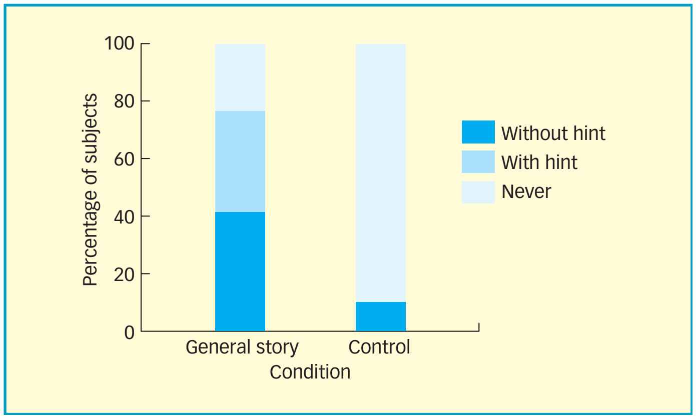
Well-defined problems:
problems in which the initial state, goal, and methods available for solving them are clearly laid out.

Ill-defined problems:
problems in which the definition of the problem statement is imprecisely specified; the initial state, goal state, and methods to be used to solve the problem may be unclear.

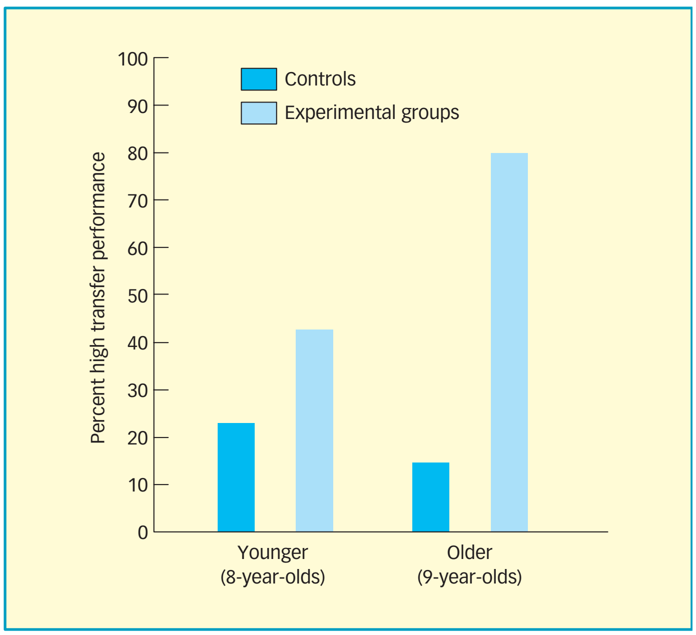
Functional fixedness:
the inflexible use of the usual function(s) of an object in problem solving.

Negative transfer:
past experience in solving problems disrupts the ability to solve a current problem.

Positive transfer:
past experiencing of solving problems makes it easier to solve a current problem.



Some of the results from Gick and Holyoak (1980, experiment 4) showing the percentage of participants who solved the radiation problem when they were given an analogy (general-story condition) or were just asked to solve the problem (control condition). Note that just under half of the participants in the general-story condition had to be given a hint to use the story analog before they solved the problem.



Percentage of children performing at a high level on the transfer test (13 or more out of 15) as a function of age (8 vs. 9) and previous relevant training (control vs. experimental). Based on data from Chen and Klahr (1999).

it are too narrow to allow the entire army to march along any one of them. Accordingly, the general has his army converge at the same time on the fortress by walking along several different roads. Gick and Holyoak (1980) found that 80% of participants solved the radiation problem when told this story was relevant (the solution is to direct low-intensity rays at the tumor from several different directions). Only 40% of participants not informed of the story-relevance solved the problem, and even fewer (10%) of those who weren't exposed to the story managed to solve it (see the figure on the left).

Most laboratory research on positive transfer has focused on the *immediate* application of knowledge and skills from one situation to a rather similar one. This is known as near transfer. In education, however, what matters is positive transfer over long periods of time to situations differing considerably from that of the original learning (far transfer). For example, educationalists hope that what students learn at school and university will enhance their ability to learn useful career skills 10–20 years later.

Chen and Klahr (1999) carried out a study on far transfer. Children aged 7–10 were trained to design and to evaluate experiments in the domain of physical science. Of central importance in the children's learning was the control-of-variables strategy involving the ability to create sound experiments and identify confounded experiments. Chen and Klahr tested for far transfer 7 months after training, including a control group of children who hadn't received training. The test assessed mastery of the control-of-variables strategy in five new domains (e.g., plant growth; biscuit making). There was clear evidence of positive transfer. Children who had received the previous training were much more likely than control children to perform well on the test (see the figure on the left).

De Corte (2003) wondered whether far transfer depends on **metacognition** (the beliefs and knowledge we have about our own cognitive processes and strategies). Students of business economics were given 7 months of training in two metacognitive skills: orienting and self-judging. Orienting involves preparing oneself to solve problems by thinking about possible goals and cognitive activities. Self-judging is a motivational activity designed to allow students to calculate accurately the effort required for successful task completion.

Far transfer was assessed when students subsequently learned statistics. Students who had received metacognitive training performed better than those who had not. Within the group that had received training, academic performance in statistics correlated positively with orienting and self-judging behavior.

DOES INSIGHT EXIST?

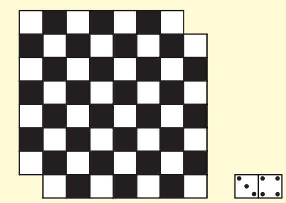
Many problems require us to work slowly but surely towards the solution. For example, solving a complicated problem in multiplication involves several processing operations that must be performed in the correct sequence. Do you agree that the overwhelming majority of problems are "grind-out-the-solution" ones? If you do, you are in for a rude shock! There are many problems in which the solution depends on **insight** or an "aha" experience involving a sudden transformation of the problem. Take the mutilated

Key Terms

Metacognition: an individual's beliefs and knowledge about his/her own cognitive processes and strategies.

Insight: the experience of suddenly realizing how to solve a problem.

checkerboard (or draughtboard) problem (see the figure on the right). The board is initially completely covered by 32 dominoes occupying two squares each. Then two squares from diagonally opposite corners are removed. Can the remaining 62 squares be filled by 31 dominoes? What nearly everyone does is to start by mentally covering squares with dominoes (Kaplan & Simon, 1990). Alas, this is not a great strategy—there are 758,148 possible permutations of the dominoes!



The mutilated checkerboard problem.

Since very few people solve this problem unaided, I'll assume you are in that large majority. However, if I tell you something you already know, the chances are much greater that you will rapidly solve the problem. Remember that each domino covers one white and one black square. If that clue doesn't do the trick, think about the colors of the two removed squares—they must have the same color. Thus, the 31 dominoes *cannot* cover the mutilated board.

The take-home message from the above problem is that how we think about a problem (the **problem representation**) is of great importance in problem solving. With many problems, we initially construct one or more problem representations. Eventually we form the correct problem representation, which involves a sudden restructuring of the problem (known as insight).

Bowden, Jung-Beeman, Fleck, and Kounios (2005) identified a part of the brain involved in insight. Participants performed the Remote Associates Test. On this test, three words are presented (e.g., "fence"; "card"; and "master"), and the task is to find a word (e.g., "post") that can go with each of them to form a compound word. Participants pressed a button to indicate whether they solved each problem using insight. In the first experiment, fMRI revealed that the anterior superior temporal gyrus [ridge] in the right hemisphere was activated *only* when solutions involved insight. In the second experiment, Beeman and Bowden recorded event-related potentials (ERPs). There was a burst of high-frequency brain activity one-third of a second before participants indicated they had achieved an insightful solution. This brain activity was centered on the right anterior temporal gyrus. This brain area seems to be especially important to insight because it is involved in processing general semantic (meaning) relationships.

Our subjective experience tells us insight occurs suddenly and unexpectedly. Here is one person's experience of producing an insightful solution on an anagram task: "The solution came to mind suddenly, seemingly out of nowhere. I have no awareness of having done anything to try to get an answer" (Novick & Sherman, 2003). Is what is true of our subjective experience also true of the underlying processes? Novick and Sherman obtained evidence that the answer is, "No." They found initially that expert anagram solvers reported far more "pop-out" or insight-based solutions than nonexperts. Then they presented participants very briefly with letter strings that could or couldn't be rearranged to form words. Even though the time period was too short to permit the anagrams to be solved, experts were much better than nonexperts at deciding which letter strings formed anagrams. Thus, some relevant processing occurs *before* "insight" anagram solutions, even though people have no conscious awareness of such processing.

What produces insight?

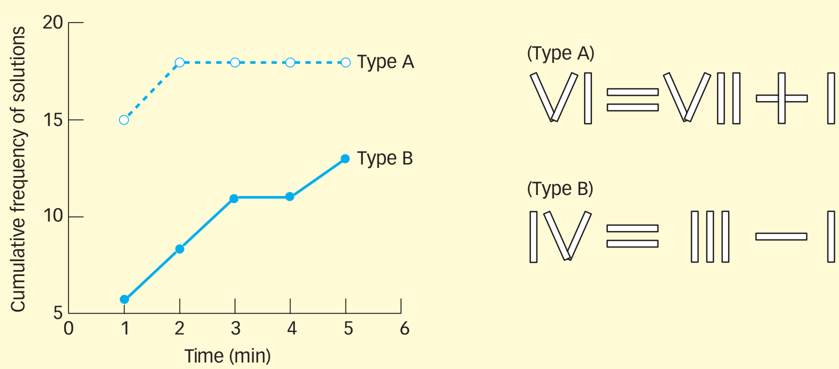
Ohlsson (1992) pointed out that we often encounter a block in problem solving because we are using an inappropriate representation of the problem. According to him, insight typically occurs only when we change such a problem representation into the correct one. This can occur in three ways:

1. *Constraint relaxation*: Inhibitions on what is regarded as permissible are removed.
2. *Re-encoding*: Some aspect of the problem representation is reinterpreted.
3. *Elaboration*: New problem information is added to the representation.

Our earlier discussion of the mutilated checkerboard or draughtboard showed how important it can be to change the problem representation via re-encoding. The key to insight in that problem is the realization that each domino covers a black square and a white one. Knoblich, Ohlsson, Haider, and Rhenius (1999) found that insight can involve relaxing constraints. They used mathematical problems involving sticks representing

Key Term

Problem representation: the way in which the problem solver represents a problem based on what seem to be its crucial features.



Two of the matchstick problems used by Knoblich et al. (1999), and the cumulative solution rates produced for these types of problems in their study.

Roman numerals (see the figure above). Each problem that was presented was initially false, and the task was to move *one* stick to turn into a true statement. For example, VI = VII + I (6 = 7 + I) becomes true by turning it into VII = VI + I (7 = 6 + I).

Knoblich et al. (1999) found that problems like the one just discussed were typically solved easily. However, most participants struggled to solve problems such as the following: IV = III − I (4 = 3 − I). The correct answer is IV − III = I (4 − 3 = 1). According to Knoblich et al., our experience of arithmetic tells us that many operations change the *values* (numbers) in an equation (as in our first example). Relatively few operations change the *operators* (i.e., plus, minus, and equal signs) as in our second example. Thus, insight on problems of the second type requires that we relax the normal constraints of arithmetic.

Many people believe that putting a problem to one side for a while or simply "sleeping on it" can be effective in getting around a block in problem solving. Psychologists use the term **incubation** to refer to this phenomenon. Dodds, Ward, and Smith (2004) reviewed 39 studies on incubation, of which 29 produced incubation effects. In general, beneficial effects of incubation were greater among participants of high ability than those of low ability. Wagner et al. (2004) found that sleep can be a useful form of incubation. Participants performed a complex mathematical task and were then re-tested several hours later. Very few of them discovered the short-cut solution to the mathematical problems on initial testing, and what was of interest was to see how many found this solution on re-testing. Of those who slept between training and testing, 59% found that short cut compared to only 25% of those who didn't.

Why does incubation work? Simon (1966) argued that it involves a special kind of forgetting. What tends to be forgotten over time is control information relating to the strategies tried by the problem solver. This forgetting makes it easier to adopt a new approach to the problem after the incubation period. Support for that viewpoint was reported by Smith and Blankenship (1991) using the Remote Associates Test (e.g., find a word ("chair") that links "wheel," "electric," and "high"). In an interference condition, participants were also presented with words emphasizing the differences in meanings of the three words (e.g., "low" is opposite in meaning to "high"). There was a strong incubation effect in this interference condition (but not in a control condition), presumably because information about the interfering words was forgotten during the incubation period.

INFORMATION-PROCESSING APPROACH

One of the greatest landmarks in problem-solving research was the publication in 1972 of Allen Newell and Herb Simon's book entitled *Human problem solving*. It was the first systematic attempt to provide an information-processing account of problem solving. Newell and Simon's central insight was that the strategies we use when tackling complex problems take account of our limited ability to process and store information. They assumed we have strictly limited short-term memory capacity and that complex information processing is typically serial (only one process at a time). These assumptions were incorporated into their General Problem Solver, a computer program designed to solve numerous well-defined problems.

Key Term

Incubation: the finding that a problem is solved more easily when it is put aside for some time; sometimes claimed to depend on unconscious processes.

According to Newell and Simon (1972), we cope with our limited processing capacity by making much use of **heuristics** or rules of thumb (e.g., only make moves that leave you closer to the goal). Heuristics have the advantage that they don't require extensive information processing. However, they suffer from the disadvantage that they aren't guaranteed to produce the problem solution. In contrast, there are **algorithms**, which are complex methods or procedures that will definitely lead to problem solution. For example, the rules of multiplication form an algorithm. Algorithms have the advantage that you are guaranteed to solve the problem if they are used correctly. However, they have the disadvantage that we often lack the processing capacity to use them properly.

The most important heuristic identified by Newell and Simon (1972) was **means–ends analysis**:

- Note the difference between the current state of the problem and the goal state.
- Form a sub-goal that will reduce the difference between the current and goal states.
- Select a mental operator that will permit attainment of the sub-goal.

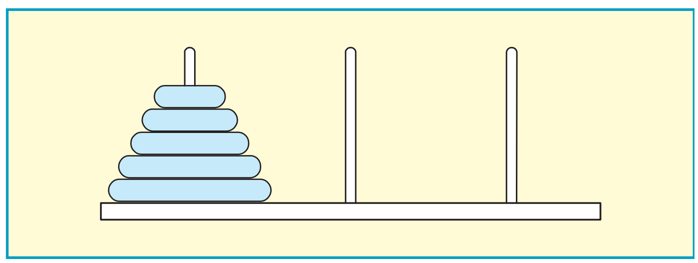
Another important heuristic is hill climbing. **Hill climbing** involves changing the present state within the problem into one that is closer to the goal or problem solution. As Robertson (2001, p. 38) pointed out, "Hill climbing is a metaphor for problem solving in the dark." It is used when the problem solver has no clear understanding of problem structure. It is thus a more primitive heuristic than means–ends analysis.

Newell and Simon (1972) gained an understanding of problem solving by asking people to solve problems while thinking aloud. These verbal reports revealed the general strategy being used on each problem. Newell and Simon then specified the problem-solving strategy in sufficient detail for it to be programmed in their General Problem Solver. In the General Problem Solver, problems are represented as a problem space. The **problem space** consists of the following:

1. The initial state of the problem.
2. The goal state.
3. All the possible mental operators (i.e., moves) that can be applied to any state to change it into a different state.
4. All the intermediate states of the problem.

As we have seen, the process of problem solving involves a sequence of different knowledge states. These knowledge states intervene between the initial state and the goal state, with mental operators providing the shift from one knowledge state to the next. It is much more difficult (or even impossible) to identify the problem space with ill-defined problems than with well-defined ones. This helps to explain why Newell and Simon (1972) focused on well-defined problems.

We can see more clearly what Newell and Simon (1972) had in mind if we consider the Tower of Hanoi problem (see the figure above). In this problem, the initial state of the problem consists of up to five disks piled in decreasing size on the first of three pegs. The goal state involves having all the disks piled in the same arrangement on the last peg. Only one disk can be moved at a time, and a large disk can't be placed on top of a smaller one. These rules restrict the possible mental operators on each move.



The initial state of the five-disk version of the Tower of Hanoi problem.

Key Terms

Heuristics:
rules of thumb that often (but not invariably) solve any given problem.

Algorithms:
computational procedures providing a specified set of steps to a solution.

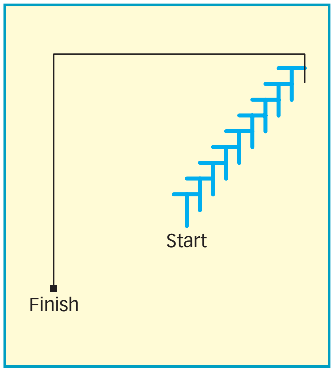
Means–ends analysis:
a **heuristic** for solving problems based on noting the difference between a current and a goal state, and creating a sub-goal to overcome this difference.

Hill climbing:
a **heuristic** that involves changing the present state of a problem into one apparently closer to the goal.

Problem space:
an abstract description of all the possible states of affairs that can occur in a problem situation.

Findings

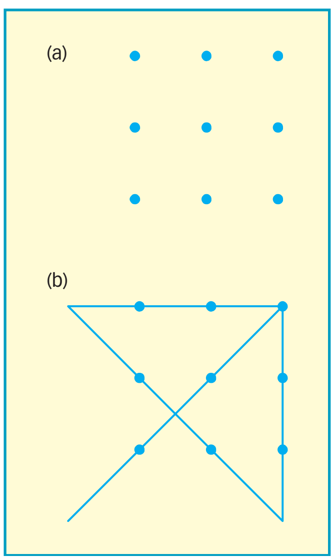
People very often use heuristics such as hill climbing and means–ends analysis when solving well-defined problems. However, they also use other strategies. For example, Simon and Reed (1976) considered performance on the



The image used in the study by Sweller and Levine (1982). Adapted from Sweller and Levine (1982).

Key Term

Progress monitoring: this is a **heuristic** used in problem solving in which insufficiently rapid progress towards solution produces criterion failure and the adoption of a different strategy.



Scheerer's (1963) nine-dot problem requires you to draw four continuous straight lines, connecting all dots without lifting your pen off the paper. Most people find it difficult to solve this because they assume all lines have to stay within the square formed by the dots. In Gestalt terms, participants have "fixated" on the shape, which results in a state of functional fixedness.

missionaries-and-cannibals problems. In this problem, missionaries and cannibals have to be transported across a river in a boat holding only two people. The cannibals must never outnumber the missionaries on either side of the river. This problem can be solved in 11 moves, but participants took 30 moves on average to solve it.

What strategies did problem solvers use? Initially, they adopted a *balancing strategy*, in which they focused on ensuring there were equal numbers of missionaries and cannibals on each side of the river. After that, they shifted to *means–ends analysis*, in which the emphasis was on moving more people to the goal side of the river. Finally, participants used an *anti-looping heuristic* to avoid any moves reversing the immediately preceding move.

Sweller and Levine (1982) decided to find out just how attached we are to means–ends analysis. They used a problem in which use of means–ends analysis would lead problem solvers to make consistently *wrong* moves. In such circumstances, would problem solvers stick with means–ends analysis or would they abandon it? What Sweller and Levine did was to give participants the maze shown in the figure on the left, but most of it was not visible to them. All participants could see the current problem state (i.e., where they were in the problem). Some of them could also see the goal state (goal-information group), whereas the others couldn't (no-goal-information group).

What do you think happened on this apparently simple problem (simple because its solution only involved alternating left and right moves)? Use of means–ends analysis requires knowledge of goal location, so only the goal-information group could have used that heuristic or rule of thumb. However, the problem was cunningly designed so that means–ends analysis wouldn't be useful, because every move involved turning *away* from the goal. Participants in the no-goal-information group solved the problem in only 38 moves on average. In contrast, of those in the goal-information group, only 10% solved the problem in 298 moves! Thus, the participants were remarkably attached to means–ends analysis, continuing to use it even when it greatly impaired problem-solving performance.

Why do we typically engage in only a modest amount of planning when involved in problem solving? According to Newell and Simon (1972), we have limited short-term capacity and so can't plan several moves ahead. Another possibility is that we find planning several moves ahead demanding in time and effort, but we can do it if necessary. Delaney, Ericsson, and Knowles (2004) obtained evidence supporting the latter possibility. They used water-jar problems in which the task was to finish up with specified amounts of water in each of three water jars. Half the participants were instructed to work out the complete solution before making any moves (the planning group). In contrast, the control group was free to use any strategy they wanted.

Delaney et al. (2004) found that the control participants showed little evidence of planning ahead. However, participants in the planning group did plan several moves ahead, and solved the problems in far fewer moves than control participants. Thus, people can plan much more effectively than is usually assumed. However, they often choose not to plan unless required to do so.

Newell and Simon (1972) assumed that problem solvers would shift strategies or heuristics if the ones they were using proved ineffective. This idea was developed by MacGregor, Ormerod, and Chronicle (2001), who argued that problem solvers use a heuristic known as **progress monitoring**. With this heuristic, the rate of progress towards the goal is assessed. Criterion failure occurs if progress is too slow to solve the problem within the maximum number of moves. Criterion failure acts as a "wake-up call" leading problem solvers to change strategy.

MacGregor et al. (2001) obtained evidence for the importance of progress monitoring in a study on the nine-dot problem (see part (a) of the figure on the left). In this problem, you must draw four straight lines connecting all nine dots without taking your pen from the paper (the solution is shown in part (b) of the figure). They used two conditions to vary the likelihood of experiencing criterion failure. As predicted, more participants in the group more likely to experience criterion failure solved the problem than those in the other group (53% vs. 31%). The take-home message is that if the strategy you are using doesn't allow you to solve a problem, the sooner you realize that is the case the better.

Evaluation

- + The Newell and Simon approach works well with several well-defined problems.
- + The approach is generally consistent with our knowledge of human information processing (e.g., limited short-term memory capacity).
- − The General Problem Solver is of limited applicability to the ill-defined problems of everyday life.
- − The General Problem Solver is better than humans at remembering what has happened on a problem but inferior at planning future moves. It focuses on only a single move whereas people often plan small sequences of moves (e.g., Greeno, 1974).
- − Newell and Simon (1972) didn't focus enough on the motivational factors causing us to shift strategies. This gap was filled by MacGregor et al. (2001) with their progress monitoring heuristic.

DECISIONS, DECISIONS

Life is full (sometimes too full!) of decisions. Which movie will I go to see tonight? Would I rather go with Dick or Harry? Which subject will I study at university? Who will I share an apartment with next year? Barry Schwartz, an American expert on decision making, believes we live in a society in which decision making is rapidly becoming more difficult because of an explosion in the choices available to us. He was in a shop called "The Gap," and wanted to buy a pair of jeans. "I told them my size, and they asked if I wanted relaxed fit, easy fit, slim fit, boot cut, button-fly, zipper-fly, acid-washed, or stone-washed. And I said, 'I want the kind that used to be the only kind'."

Evidence that we sometimes simply give up when confronted by too many choices was reported by Iyengar and Lepper (2000). They set up a tasting booth in Draeger's supermarket in Menlo Park, California. On one weekend, this booth offered six kinds of jelly, but it offered 24 kinds of jelly on another weekend. Nearly 30% of shoppers faced by six choices bought some jelly, but the figure slumped to only 3% when there were 24 choices.

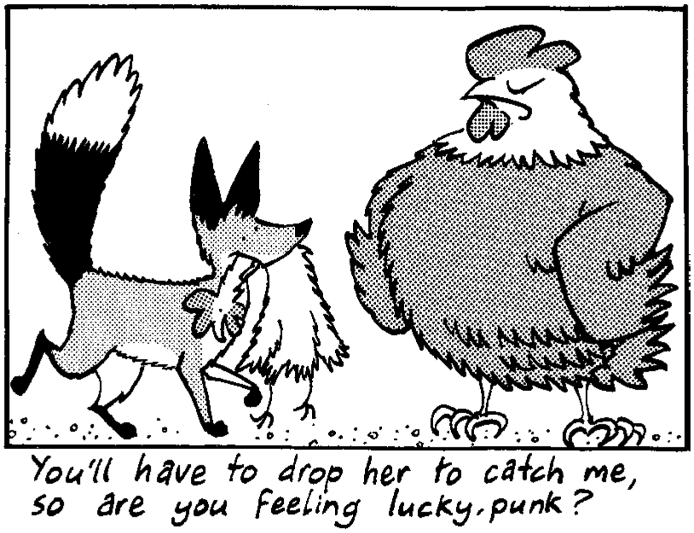
The study of decision making is of direct relevance to real life. For example, Carlson and Russo (2001) showed potential jurors a video explaining the importance of not making decisions before seeing all the evidence. After that, they were presented with affidavits [written declarations made under oath], case backgrounds, and opening arguments. After each new piece of evidence was presented, the participants decided whether it benefited the plaintiff or the defendant. Most participants showed "pre-decisional distortion"—they often regarded the new evidence as supporting whichever party (plaintiff or defendant) they favored before it was presented. Pre-decisional distortion may allow jurors to create a coherent account of what they think happened but can obviously be very bad news for innocent defendants!

Worrying evidence that important real-life decisions may be inadequate was reported by Elstein et al. (1999). They presented doctors working in critical care with six realistic case scenarios, asking them to assess the benefits of various treatments and to decide on appropriate treatment. There were two versions of each case scenario differing in the probability of survival, with half of the doctors receiving each one. Amazingly, neither treatment choice nor perceived treatment benefit depended on the probability of survival! The doctors simply followed their typical approach to treatment regardless of the precise circumstances.

How do we decide how good a decision is? That sounds like a strange question, but it has important implications. Most people argue that what really matters is the outcome—did the decision lead to the desired consequences? However, many experts argue that most decisions are like gambling in that they are made under uncertainty. Thus, a decision can be "good" in the sense of being based on sound reasoning, but may nevertheless produce undesirable consequences. Thus, it can make sense for a surgeon to claim, "The operation was a success but unfortunately the patient died."

Too much choice!

Many of us would think that choice is a good thing but Howe, Butt, and Timmons (2004) say that psychology experiments prove otherwise. For example, one experiment had subjects comparing chocolate chip cookies from a jar of 10 cookies with those from a jar of two cookies. Participants rated the cookie from the smaller jar better, more valuable, more desirable to eat in the future, and more attractive as a consumer item than the one from the larger jar. In reality the cookies were identical. Participants felt that more choice had made the sample less desirable.



LOSSES AND GAINS

All of us strive to achieve gains (e.g., emotional; financial; academic success) while avoiding losses. You would probably argue that we make decisions so as to maximize the chances of making a gain and minimize the chances of making a loss. Suppose someone offered you $200 if a tossed coin came up heads and a loss of $100 if it came up tails. You would jump at the chance (wouldn't you?) given that the bet provides an average expected gain of $50 per toss.

Here are two more decisions. Would you prefer to make a sure gain of $800 or an 85% probability of gaining $1000 and a 15% probability of gaining nothing? Since the expected value of the latter decision is greater than that of the former decision ($850 vs. $800, respectively), you might well choose the latter alternative. Finally, would you prefer to make a sure loss of $800 or an 85% probability of losing $1000 with a 15% probability of not incurring any loss? The average expected loss is $800 for the former choice and $850 for the latter one, so you go with the former choice don't you?

The first problem above was taken from Tversky and Shafir (1992) and the other two problems come from Kahneman and Tversky (1984). In all three cases, most participants did *not* make what appear to be the best choices. Two-thirds of them refused to bet on the toss of a coin, and a majority preferred the choices with the smaller expected gain and the large expected loss! What on earth is going on here? Kahneman and Tversky (1984) accounted for such findings within their prospect theory based on two key theoretical assumptions:

1. People identify a reference point generally representing their current state.
2. People are much more sensitive to potential losses than to potential gains; this is known as **loss aversion**.

Both of the above assumptions are shown in the figure on the left. The reference point is the point at which the line labeled losses and gains intersects the line labeled value. The positive value associated with gains increases relatively slowly as gains become greater. In contrast, the negative value associated with losses increases relatively rapidly as losses become greater.

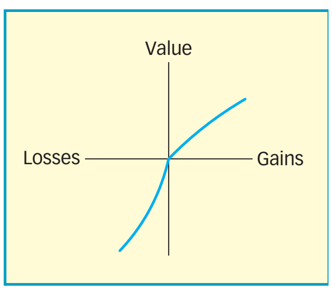
There is further prediction following from prospect theory. When people make decisions, they attach more weight to low-probability events than they merit according to their actual probability of occurrence. In contrast, high-probability events receive less weight than they deserve. This helps to explain the human tendency for risk seeking with gains (e.g., gambling on remote events such as winning a fortune on the lottery) and for risk avoidance with losses (e.g., buying insurance) (Jonathan Evans, personal communication).

Prospect theory does a good job of explaining the findings discussed earlier. If people are much more sensitive to losses than to gains, they will be unwilling to accept bets involving potential losses even though the potential gains outweigh the potential losses. They will also prefer a sure gain to a risky but potentially greater gain. Finally, please note that prospect theory does *not* predict that people will always avoid risky decisions. If offered the chance of avoiding a loss (even if it means the average expected loss increases from $800 to $850), most people will take that chance because they are so concerned to avoid losses.

Prospect theory can be contrasted with previous theoretical views based on the notion of "rational man" (or "rational person"). According to this approach, we work systematically through the available evidence and make the decision most likely to produce a desirable outcome.

Key Term

Loss aversion: the notion that individuals are more sensitive to potential losses than they are to potential gains.



A hypothetical value function. From Kahneman and Tversky (1984). Copyright © American Psychological Association. Reprinted with permission.

Case Study: *Picking Lottery Numbers*

In general, people have a very poor understanding of randomness and probability, as evidenced by the types of numbers commonly selected in national lotteries. Even people who claim to understand that any given number is as likely to come up as any other will be heard to despair: "Oh, I'll never win with that—four numbers in a row!," or "All my numbers are bunched up under 20—I'd better spread them out a bit to get a better pattern." In fact, statistics suggest that you're actually better off picking numbers with a skewed or bunched appearance: you're no more likely to win, but in the unlikely event that you do, you'll be less likely to have to share your prize with anyone else!

This notion is found in **normative theories**, which focus on how people *should* make decisions rather than on how they actually make them. For example, von Neumann and Morgenstern's (1947) utility theory claimed that people try to maximize *utility*, which is the subjective value we attach to an outcome. When we choose between options, we assess the expected utility or expected value of each one as follows:

Expected utility = (probability of a given outcome) × (utility of the outcome)

As we will see, prospect theory for all its imperfections is clearly superior to normative theories.

Full-fat milk?

Using this argument we can offer an explanation as to why food retailers might advertise or label full-fat milk as "94% fat free" in order to draw customer attention away from its high fat content when compared to skimmed milk. Retailers may have decided to reverse the tendency for customers to associate higher fat content in milk with bad dietary habits by stating the high-percentage fat-free quality of milk.

Findings

Suppose we give different people precisely the same problem phrased in two different ways. In one version, the potential gains associated with various decisions are emphasized, whereas the potential losses associated with the decisions are emphasized in the other version. Since the problem is exactly the same, common sense would suggest that people would make the same decisions regardless of problem phrasing. According to prospect theory, changing the wording should matter because people are more motivated to avoid losses than to achieve gains. This is known as a **framing effect**, meaning the decision is influenced by irrelevant aspects of the situation.

The Asian disease problem has often been used to study the framing effect. Tversky and Kahneman (1987) told participants there was likely to be an outbreak of an Asian disease in the United States, and it was expected to kill 600 people. Two programs of action had been proposed: Program A would allow 200 people to be saved; Program B would have a 1/3 probability that all 600 people would be saved and a 2/3 probability that none of the 600 would be saved. When the issue was expressed in this form, 72% of participants favored Program A, although the two programs if carried out several times would on average lead to the saving of 200 lives. This is a framing effect based on loss aversion.

Other participants in the study by Tversky and Kahneman (1987) received the same problem negatively framed: Program A would lead to 400 people dying, whereas Program B carried a 1/3 probability that no one would die and a 2/3 probability that 600 would die. With this wording, the findings were very different—78% of participants chose Program B, a framing effect resulting from loss aversion.

Why are people more sensitive to losses than to gains? Interesting evidence was provided by Kermer, Driver-Linn, Wilson, and Gilbert (2006). Participants were initially given $5, and forecasted how they would feel if they won $5 on the toss of a coin or lost $3. They forecast that losing $3 would have more impact on their happiness immediately and 10 minutes later than would gaining $5, which is a clear example of loss aversion. In fact, however, participants who lost felt happier than they had predicted at both time intervals, and the actual impact on happiness of losing $3 was no greater than the actual impact of gaining $5.

Why don't we learn from experience that losses often have less negative emotional impact than we had anticipated? One reason is that people often rationalize or explain away losses in ways that are difficult to predict ahead of time. For example, Kermer et al. (2006)

Key Study

Wang (1996): The framing effect

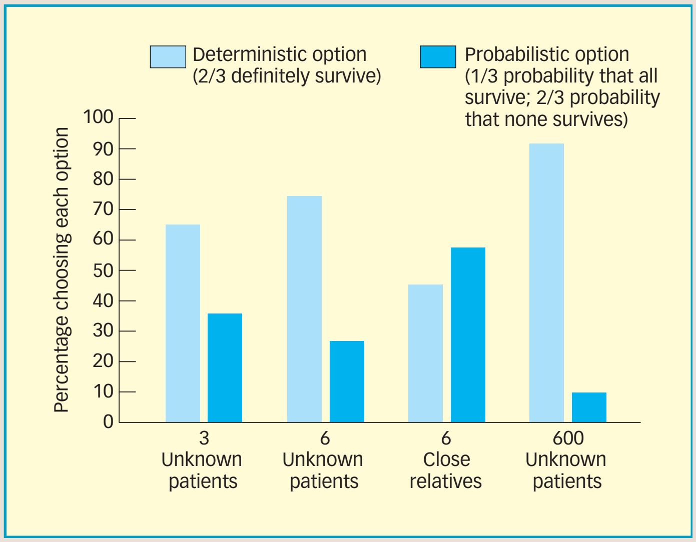
Wang (1996) carried out important research on the framing effect. Wang pointed out that our decision making in everyday life is very often influenced by social and moral considerations. Prospect theory is limited because it fails to consider such considerations. Wang used various versions of the Asian disease problem in his research. Participants chose between definite survival of two-thirds of the patients (the deterministic option) and a 1/3 probability of all patients surviving and a 2/3 probably of none surviving (the probabilistic option). The deterministic option is much better than the probabilistic one, because it leads on average to the survival

Key Terms

Normative theories: as applied to decision making, theories focusing on how people should make decisions.

Framing effect: the influence of irrelevant aspects of a situation (e.g., wording of the problem) on decision making.

of twice as many patients. As predicted, the overwhelming majority of participants chose the deterministic option when the problem was phrased in terms of 600 unknown patients (see the figure below).



Effects of fairness manipulation on choice of the option with selected or with non-selected survivors. Data from Wang (1996).

More interesting and dramatic findings were obtained by Wang (1996) when the Asian disease problem was phrased in terms of 6 unknown patients, 3 unknown patients, or 6 close relatives. There was a large increase in the percentage of participants choosing the probabilistic option with small group size, especially with close relatives (see the figure above). Why was this? Participants chose the probabilistic option with close relatives because it seemed *fair* to give all of them the same chances of surviving. Thus, social and moral factors (not considered directly by prospect theory) can outweigh the rational approach of simply trying to maximize the numbers of people saved.

More evidence that social factors are important was reported by Wang, Simons, and Brédart (2001). They studied the framing effect using a life-and-death problem involving either 6 billion human lives or 6 billion extraterrestrial lives. There was the usual framing effect when human lives were at stake, but no framing effect at all when only extraterrestrial lives were involved.

Discussion points

1. Think of an experience in your own life where the decision you made was determined by the situation. How might the outcome have been different if the situational variables had been different?
2. Your neighbor's dog has been hit by a vehicle and seems to have broken a leg. Would what you do about this vary depending on how you get on with your neighbor?

KEY STUDY EVALUATION

Wang's (1996) important research was influential in showing that previous research designed to test prospect theory had been too narrowly based. More specifically, Wang showed that we can only understand framing effects fully by taking account of the social and moral context in which we arrive at decisions. However, it is important to note that Wang's research was laboratory-based, and might not apply in the real world. Which option would you choose if you were placed in the horrific position of deciding between definitely saving 4 out of 6 close relatives or probably seeing all 6 die? Note also that there was only a small majority in favor of the probabilistic option with 6 close relatives. This suggests that there are important individual differences involved in making that kind of agonizing choice.

found that participants who had lost $3 focused much more on the fact that they nevertheless finished with a profit of $2 than they had predicted beforehand.

Rottenstreich and Shu (2004, pp. 458–459) argued that decision making can be based on "two separate systems—an affective [emotional] system and a perhaps more cognitive system compatible with prospect theory." Supporting evidence comes in a study by Rottenstreich and Hsee (2001). American participants imagined they might win a $500 coupon that could be used for tuition payments or towards the costs of a holiday in Paris, Venice, or Rome. It was assumed that the prospect of a holiday abroad would create more emotion than using the money for tuition. Different groups of participants were told that the chances were either 1% or 99% of winning the coupon. When there was only a 1% chance, most participants decided they would use the coupon for a holiday. In contrast, most participants given a 99% chance of winning decided they would use the coupon for tuition fees. Thus, the emotional system was dominant when there was a small hope of winning the prize, whereas the cognitive system was dominant when the odds were very favorable.

Another limitation of prospect theory is that it ignores individual differences, in spite of the fact that we all know some people are more willing to take risks than others. Josephs, Larrick, Steele, and Nisbett (1992) used a task in which individuals chose between a sure win of $10 versus a 50% chance of winning $20 on a gamble. Individuals low in self-esteem were 50% more likely than those high in self-esteem to choose the sure gain. Why was this? People with low self-esteem are concerned that negative or threatening events will reduce their fragile self-esteem.

A final limitation with prospect theory is that it ignores cross-cultural differences. Do you think Americans would be more inclined to take risky financial decisions than Asians? I hazard a guess that your answer is, "Yes." In fact, the correct answer is the opposite. Weber and Hsee (2000) discussed several of their studies in which they found Americans *less* inclined than Chinese individuals to make risky financial decisions. The main reason is that Chinese individuals can afford to take greater financial risks because they enjoy more protection from their family and social networks. As predicted, Americans with strong networks were more willing than those with weak networks to make risky financial decisions, and Chinese people with weak networks were risk-averse.

Evaluation

+ Prospect theory provides a more accurate account of human decision making than previous theories.
+ The notion that we attach more weight to losses than to gains provides an explanation for many phenomena (e.g., loss aversion; framing effect).
– The theory doesn't consider the impact of social and emotional factors on decision making (e.g., Rottenstreich & Hsee, 2001; Wang, 1996).
– The theory neglects individual differences in the willingness to take risks (e.g., Josephs et al., 1992).
– The theory ignores cultural differences in risk taking (e.g., Weber & Hsee, 2000).
– As Hardman and Harries (2002, p. 76) pointed out, "There is no apparent rationale for . . . the value function . . . The value function is descriptive of behavior but does not go beyond this." In other words, we aren't given a convincing explanation of *why* people are more sensitive to losses than to gains. As we have seen, part of the answer is that we tend to exaggerate how badly we will feel about losses (Kermer et al., 2006).

WHAT WILL PEOPLE THINK?

As Tetlock (1991, p. 453) pointed out, "Subjects in laboratory studies . . . function in a social vacuum . . . in which they do not need to worry about the interpersonal consequences of their conduct." This is an important point, because our everyday decision making is strongly influenced by the social and cultural context in which we live.

More specifically, as Tetlock (2002) argued, we often behave like intuitive politicians concerned to justify our decisions to other people. In this section, we consider evidence relating to Tetlock's social functionalist approach.

Findings

We can see how social factors influence decision making by focusing on the behavior of New York cab drivers. Camerer, Babcock, Loewenstein, and Thaler (1997) studied how many hours these cab drivers worked each day. From a purely economic perspective, they should work fewer hours when business is slack and longer hours when business is good. In fact, many cab drivers do precisely the opposite. They set themselves a target income for each day, and only stop work when they have reached it. Thus, New York cab drivers work unnecessarily long hours when business is poor and miss out on easy money when business is good. Why do they behave in this apparently illogical way? The answer is that their behavior is "an adaptive response to no-excuses accountability pressures from the home front to bring home the bacon" (Tetlock & Mellers, 2002, p. 98).

We can see the importance people attach to being able to justify their decisions to others in a study by Simonson and Staw (1992). The study focused on the **sunk-cost effect**, which involves a tendency to throw good money after bad in an attempt to recoup one's losses. Participants were told about a beer company selling light beer and non-alcoholic beer. They had to recommend which product should receive an additional $3 million for advertising purposes. When they had done that, they were informed that the president of the company had made the same decision, but this had produced disappointing results. The participants were then told the company had decided to allocate an additional $10 million from the advertising budget to be divided between the two products.

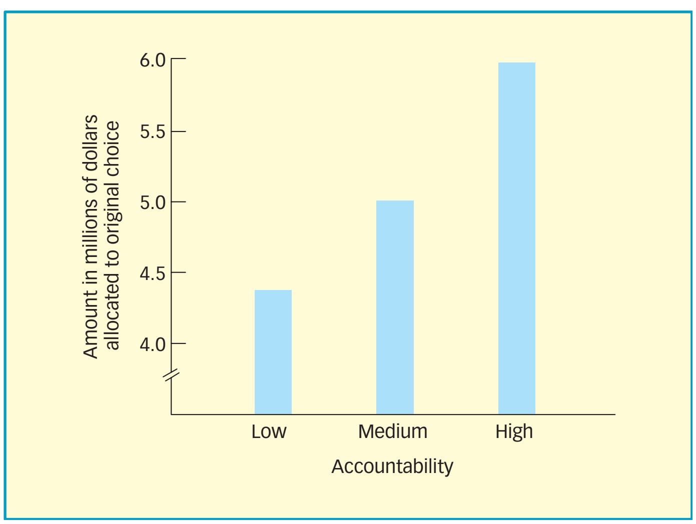
The three key conditions varied in the emphasis given to justifying one's decision to others:

1. High-accountability condition: Participants were told that information about their decision might be shared with other students and instructors. They were also asked to give permission to record an interview about their decision.
2. Medium-accountability condition: Participants were told the information provided to them should be sufficient to make a good decision.
3. Low-accountability condition: Participants were informed that their decisions would be confidential.

Key Term

Sunk-cost effect: expending additional resources to justify some previous commitment (i.e., throwing good money after bad).

Simonson and Staw (1992) assessed the extent of the sunk-cost effect (putting extra money into the product that had already fruitlessly received previous advertising money). The tendency towards a sunk-cost effect was greatest in the high-accountability condition and lowest in the low-accountability condition (see the figure on the left). Participants in the high-accountability condition tried to justify their previously ineffective course of action (i.e., investing in one type of beer) by increasing their commitment to it.



Millions of dollars allocated to original choice (sunk-cost effect) as a function of accountability. Data from Simonson and Staw (1992).

Schwartz, Chapman, Brewer, and Bergus (2004) found that even the decisions of medical experts can be swayed by considerations of accountability. Doctors were presented with the case of a patient with osteoarthritis for whom anti-inflammatory drugs had proved ineffective. In the two-option condition, they chose between referring the patient to an orthopedic specialist to discuss surgery or combining referral with prescribing an untried anti-inflammatory drug. In the three-option condition, there were the same two options plus referral combined with a different untried anti-inflammatory drug. The doctors were *more* likely to select the referral-only option in the three-option condition, which seems contrary to common sense. This bias was greater when they were made accountable for their decisions. What is going on here? In the three-option condition, it is very difficult to justify selecting one anti-inflammatory drug over the other one. Selecting the remaining option (i.e., referral only) made it easier for the doctors to justify their decision.

Evaluation

- + The assumption within the social functionalist approach that our decisions in everyday life are generally influenced by social and cultural factors is absolutely right.
- + We often experience pressure to justify our decisions to others, and this is the case even with experts (e.g., Schwartz et al., 2004).
- − Important factors within prospect theory (e.g., our greater sensitivity to losses than gains) are ignored by the social functionalist approach.
- − Tetlock and others favoring the social functionalist approach have often criticized other researchers for conducting experiments not making any real demands on social responsibility. Ironically, much the same can be said of their own research!

COMPLEX DECISION MAKING

So far we have mainly considered decision making applied to fairly simple problems. In real life, however, we sometimes have to make very complex decisions (e.g., Shall I marry John? Shall I move to Australia?). How do we approach such decisions? According to multi-attribute utility theory (Wright, 1984), the decision maker should go through the following stages:

1. Identify dimensions relevant to the decision.
2. Decide how to weight those dimensions.
3. Obtain a total **utility** (i.e., subjective desirability) for each option by summing its weighted dimensional values.
4. Select the option with the highest weighted total.

We can see how this theory might work in practice by considering what happens when someone decides which apartment to rent. First, consideration is paid to the relevant dimensions (e.g., number of rooms; location; rent per week). Second, the relative utility of each dimension is calculated. Third, the various apartments being considered are compared in terms of their total utility, and the individual chooses the one with the highest total utility.

As you have probably guessed, people rarely follow the dictates of this theory in real life. There are various reasons for this. The procedure can be very complex, the set of relevant dimensions can't always be worked out, and the dimensions themselves may not be clearly separate from each other.

BOUNDED RATIONALITY

Herb Simon (1957) drew an important distinction between unbounded rationality and bounded rationality. Within models of unbounded rationality (multi-attribute utility theory is an example), it is assumed that all relevant information is used by the decision maker. As a consequence, people are in a position to make the best possible decision or choice. This approach doesn't bear much relationship to real life. As Klein (2001, p. 103) pointed out, "In the majority of field settings, there is no way to determine if a decision choice is optimal owing to time pressure, uncertainty, ill-defined goals, and so forth."

Simon (1957) argued that we possess bounded rationality rather than unbounded rationality. The essence of **bounded rationality** is that we produce reasonable or workable solutions to problems in spite of our limited processing capacity by using short-cut

Key Terms

Utility:
the subjective desirability of a given outcome in decision making.

Bounded rationality:
the notion that people are as rational as their processing limitations permit.