# The half-second delay: what follows?

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**ABSTRACT There is an increasing body of evidence that only a minuscule proportion of the sensory data processed by the unconscious mind (capable of processing approximately 11 million bits per second) is referred to the conscious mind (capable of processing approximately 50 bits per second). It is also clear that conscious awareness of stimuli from the environment lags actual perception by approximately half a second, but that a backward referral of subjective experience results in a individual’s perception of the stimulus and its conscious awareness as simultaneous. These findings challenge the primacy and supremacy of conscious processing of information on which a substantial proportion of educational practice and policy is based, and suggest a re-evaluation of the nature of teacher competence and expertise.**

## In search of brain-based education?

That is the title of an article by John Bruer, who argues that most of what is known about the physiology of brains is inadequate to inform teaching and learning (Bruer, 1999). He cites the example of brain-lateralization, which has spawned a number of teaching approaches that are designed to complement ‘left-brain’ and ‘right-brain’ approaches to learning. However, as he points out, the research that shows that some activities are lateralized in one side of the brain or the other deals with highly specialized activities, and that all educationally significant activities require both sides of the brain. While some of the ‘prescriptions’ claiming to emerge from research on brain-lateralization may have benefit, Bruer concludes that none are currently grounded in evidence.

Similar conclusions follow from the research on learning styles. While some studies claim to show that changing teaching to cater for individuals’ learning styles produces improvements in learning, other studies have found that forcing learners to learn in a style different from their preference can increase learning (Adey, Fairbrother, Wiliam, Johnson, & Jones, 1999). The message from the learning styles research is that teaching should cater for a range of learning styles—but the same conclusion arises from most other theoretical stances on learning too.

At the risk of adding one more item to the pile of unwarranted extrapolations from cognitive science, in this paper I want to explore the consequences of some little-known but highly significant research findings that I think have profound implications for the way that we think about education in general, and the process of teaching in particular. The remainder of this and the next section of this paper draw heavily on a very readable account of the nature of consciousness written by Tor Nørretranders (1998).

There is an increasing body of evidence that only a minuscule proportion of the sensory data processed by the unconscious mind is referred to the conscious mind. Table 1 below is based on data from Zimmerman (1989) and shows that the bandwidth of consciousness processing is far less than the bandwidth of the sensory inputs received generated by the body’s sensory systems.

Now of course, it could be that most of the vast amount of information received by the body’s sensory systems is simply ignored. In other words that all but the information in conscious perception is discarded by the brain, or doesn’t even arrive at the brain—for example, it could be that sensory data that is not the subject of ‘attention’ is not even processed. However, several strands of research evidence suggest that this is not so.

*Insert Table 1 about here*

For example, there is a substantial body of evidence that subliminal (literally ‘below the threshold’) perception (ie perception that is not available to consciousness) can be used in conscious processing. It is now well known that stimuli that are perceived for too short a period to be consciously perceived (ie subliminal) can, nevertheless, ‘prime’ respondents in the way that they answer subsequent questions (Kihlstrom, 1987). Further evidence for the important of sensations that are not perceived consciously comes from descriptions of cases of patients with damage to certain parts of the brain. Many of these patients are, to all intents and purposes, blind, in that they are not aware of being able to see anything. Yet, in tests of visual perception, they consistently score well above chance levels. This ‘blindsight’ can only be explained by a level of visual processing that is not available to consciousness (Sacks, 1995).

It is also clear that this filtering process is largely, if not completely, determined by previous experience. In the well-known optical illusion shown in figure 1, generally known after the German psychologist Franz Carl Müller-Lyer, as the Müller-Lyer illusion the two vertical line segments are exactly the same length. However, the left-hand vertical appears to be much shorter than the one on the right. The most convincing explanation of this has been provided by Richard Gregory who suggests that the illusion is caused by the visual processing system’s interpretation of the left hand figure as an external corner of an object, while that on the right is an internal corner (Gregory, 1966). Since the visual perception system ‘knows’ that objects that are further away are smaller, it compensates for this by creating a *perception* of the internal corner as larger, because it must be further away. As Hundert (1995, p.211) observes:

> It is tempting to call this phenomenon of the accommodation of our plastic visual input analyzers to the realities of depth perspective and size constancy in our world a “natural phenomenon”—except for the simple fact that such rectilinear lines do not exist *in nature!* (emphasis in original)

And indeed, it has been found that people raised in cultures who do not build rectilinear structures do not experience the Müller-Lyer illusion (Deregowsky, 1974). Even something as basic as what we see, therefore, is not ‘transparent’, but rather is filtered by the unconscious processing that takes place prior to referral to consciousness.

*Figure 1 about here*

Evidence that this filtering takes place *after* unconscious perception is provided by a study relating to another well-known optical illusion (known as a size-contrast illusion). The two central circles in figure 2 are actually the same size, but the circle on the left appears to be bigger, because of the presence of the smaller surrounding circles. However Aglioti, De Souza and Goodale (1995) found that when the visual illusion was recreated with three dimensional plastic discs, while participants continued to see the circle surrounded by small discs as smaller, a videotape of the participants reaching to pick up the central disc showed exactly the same finger separation for the two situations. In the words of the title of the paper, these size-contrast illusions “deceive the eye but not the hand”, or, in terms of the present analysis, visual illusions deceive the conscious, but not the unconscious mind.

*Figure 2 about here*

Another interesting effect is observed if one holds both one's hands in front of one's face, one hand being held twice as far away from the eyes as the other. The laws of physics tell us that the nearer hand should be seen as twice as large (and as having four times the area) of the further hand, but for most people, this is not what is observed.

A final example of the role of unconscious processing in perception is provided by the effect of 'colour constancy' whereby objects do not appear to change colour as the lighting conditions vary, or as the object moves to a region where the ambient lighting conditions are different. Again, the laws of physics tell us that the actual wavelength of the light impacting the retina changes, but this is not perceived as a change in colour. The unconscious mind's *theoretical* model—that the object has not changed colour—overrides the raw sense data and creates in the conscious mind the phenomenon of colour constancy.

While our perception of the real world therefore appears as a transparent process, the 'physical' model of sense data being referred to consciousness in a direct and unproblematic way simply does not hold up:

> We do not experience the world as raw data. When our consciousness experiences the world, the unconscious discarding of sensory information has long since interpreted things for us. *What we experience has acquired meaning before we become conscious of it*. (Nørretranders, 1998, p.187, original emphasis)

It is also important to note that the meaning that is attached to experience includes affective content. Traditional models of affect posit that data are processed consciously, and then referred for an affective reaction. In other words, first we decide what we think, and then we decide how we feel about it. However, the evidence provided by Damasio (1994) indicates that the real order of things is likely to be the reverse of this. The unconscious processing that occurs prior to referral to consciousness invests the sense data with affect *before* referral to consciousness. In other words, what we feel about something tells us what we think. Further elaboration of these ideas is beyond the scope of this paper, but the interested reader is referred to Damasio's work which provides a very readable introduction to recent research on affect and reasoning.

Now all this processing and filtering of sense data prior to referral to consciousness must take some time, but when experimenters attempted to work out exactly how long this took, the answer was so surprising that many people have found it hard to accept.

## The half-second delay

In the 1960s and 1970s, two German neurophysiologists attempted to estimate exactly how long it took for a decision to initiate a movement (for example moving a finger) that resulted in action. They found that any action such as flexing a finger is presaged by an increase in electrical activity (what they termed a readiness potential) that appears to correspond to the brain preparing to carry out an action by determining how it is to be done. What was surprising was that, on average, the increase in readiness potential began 0.8 seconds before the finger was flexed. The question that then arises is when is the conscious decision to act actually made? The classical answer would be that the conscious decision to act must occur at the same time as the onset of the increase in readiness potential, but this would suggest that it took over three-quarters of a second for this decision to result in action, which doesn't accord with either our experience or our 'common sense'. However, the alternative is even less plausible, and that is that the increase in readiness potential *precedes* the decision to act.

The matter was settled by a series of very elegant experiments reported by Benjamin Libet in 1979 in which participants were asked to flex a finger whenever they felt like doing so. In order to answer the question as to the sequence of events, it was necessary to get data on three events—when the increase in readiness potential began, when the conscious decision was made, and when the finger moved. The first and last of these were easy to obtain. In order to get reliable data on when the conscious decision was made, the participants were asked to look at a clock face with a single hand which made one revolution every 2.56 seconds. Asking the participants to note the position of the hand when they decided to flex the finger provided a reliable measure of when the decision was taken.

The results were highly consistent, and showed that the increase in readiness potential began 0.55 seconds before the act, but much more surprisingly, the conscious decision occurred 0.2 seconds before the act. In other words, the conscious decision to act occurs 0.35 seconds *after* the body has started the mechanism to act!

Although this result is astonishing, and provoked much controversy (see Nørretranders, 1998, pp. 220-250 for a discussion) Libet's interpretation of these events did actually explain experimental and other phenomena that had been observed. For example, many people have had the sensation of looking at the second-hand of a clock for more than a second, and yet the second hand does not appear to move. The delay between experience and conscious awareness seems the most likely explanation.

Libet's explanation also explained some experimental results that Arthur Jensen had collected in the 1960s. In collecting the reaction times of individuals, which averaged 0.25 seconds, he suspected that some of the participants were deliberately slowing down their reactions (because they distrusted what he would do with the data). Jensen then asked the participants to increase their reaction times gradually, but none of the participants could do this. As soon as they tried to slow down their reactions at all, the reaction times increased to over half a second (reported in Libet, 1981 pp185-186).

These and many similar experiments show that conscious awareness of stimuli from the environment lags actual perception by up to half a second. Information from different parts of the body about simultaneous events arrive at the brain at different times, but the brain assembles these data so that an individual perceives the stimulus and its conscious awareness as simultaneous. Michael Gazzaniga sums it up thus:

> "Major events associated with mental processing go on, measurably so, in our brain before we are aware of them. At the same time, these done deals do not leave us feeling we are watching only a movie of our life. Because of temporal referral mechanisms, we believe we are engaged in effecting these deals." (Gazzaniga, 1999 pp73-74)

## Educational implications

Much (if not most) of our current practice in education is based on a simplistic model of brain function—one in which data is received in a way very similar to that in which it is transmitted, passed directly to consciousness, and of which more or less sense is made. This criticism applies just as much to so-called 'constructivist' views of learning as to more traditional models. Recently, there has been recognition that implicit learning (learning in which you don't know that you're learning and you don't know what you've learnt) is an important element of learning, but much of this research is relatively atheoretical, and rarely ventures beyond description.

The central feature of the argument I want to advance here is that traditional theories of learning will not serve, either as descriptions of what does happen, or of prescriptions of what should happen. Acceptance of the significance of the neurophysiological evidence outlined above requires a radical reconceptualisation of both learning and teaching.

Some important work has been done in this regard. *Hare Brain, Tortoise Mind* by Guy Claxton (1997) provides compelling evidence about the centrality of unconscious processing in learning, but in the remainder of this paper I want to explore the relevance of these experimental findings to two aspects of the activities of teachers: teachers' cognitive activities in day-to-day teaching, and assessment.

## Teachers' cognitive activities

The failure of psychology to impact on the improvement of teaching competence in general, and on teacher education specifically has been lamented for many years. In his influential book *The reflective practitioner,* Donald Schön (1983) attributes this to the pursuit of a project of technical rationality which he regards as epistemologically inappropriate, in that technical rationality seeks to separate theory (based on explicit knowledge—knowing *that*) from practice (often based on implicit knowledge—knowing *how*). Schön argues that competence is achieved not by the reflection *on* action but by reflection *in* action. However, as Tomlinson (no date) points out, technical rationality may also fail because it is inadequate to illuminate practice. As Tomlinson says:

> I think it would be fair to say that when education consulted the psychology cupboard some decades ago, it didn't find too much of direct relevance to the promoting of relatively complex human learning, in pupils of varying ages, in typically complex social settings (p. 3).

Compared with other areas of research in education, the cognitive activity of teachers has received relatively little attention. That research does acknowledge that a lesson delivered by an experienced teacher consists of a number of 'scripts' (Schank & Abelson, 1977), 'frames' (Minsky, 1975) or 'images' that are linked together. However, it is common to regard the assembly of these scripts as an 'automatic' process:

> Much of their instruction is accomplished though previously developed routines that minimize the need for conscious decision making and that tend to be played out once they are begun. Using these images and routines, teachers proceed on 'automatic pilot' so long as events develop as expected. Their attention is focused on keeping the activity moving at a good pace, managing the group, and monitoring the involvement of individuals. This is accomplished mostly automatically using routines and heuristics so long as pupil response remains within the expected and acceptable levels of tolerance. (Bromme & Brophy, 1986, p. 116)

While this analysis portrays, I think accurately, the lack of conscious decision-making in much of teachers' day-to-day classroom activities, I want to suggest that regarding the teacher's 'normal' activity as one of being on 'automatic pilot' is unhelpful, and underplays the significance of the unconscious cognitive processing that takes place during this activity. To illustrate this, let us first consider an aspect of the nature of expertise in playing chess.

Chase and Simon (1973) showed chessboards, on which were placed a number of pieces, to an expert, an intermediate and a novice chess player for five seconds, after which they were asked to reconstruct what they had seen (this process was repeated several times, with different arrangements of pieces). The arrangements on the chessboards were produced in two ways. Half of the chessboards were positions from actual games either in the middle of a game (with 24 to 26 pieces), or at the end of a game (12 to 15 pieces). The other positions were generated by taking the pieces from one of the actual games and re-arranging them randomly. The results are shown in table 2. As can be seen, experts were slightly *worse* than intermediates and novices when the pieces were arranged randomly, but were four times better when the pieces were arranged in a pattern from a real game.

*Table 2 about here*

In their discussion of this result, Chase and Simon suggest that the much better performance of experts with 'real' chessboards stems from an ability to 'read' a chessboard in terms of a series of standard configurations of pieces that they have learnt through their experience as chess players.

This is analogous to a much more prosaic task in which we ask someone to memorise a seven-letter string. The seven letter string "p•a•n•c•a•k•e" is easier to memorise than "a•m•o•e•b•a•e", which in turn is easier to memorise than "j•k•q•x•z•q•g" because the first two can be processed as a whole (ie as a 'gestalt'), although the second probably also requires some familiarity with conventions of Latin spelling. The third string can be memorised by the conscious construction of a mnemonic, but that is likely to take some time.

From this perspective, expertise is not the result of being able to deploy a small number of highly general and abstract strategies but rather the ability to 'read' a situation in terms of a very large number of highly specific configurations—Simon (1980) estimated that a chess grandmaster might have a repertoire of as many as 50,000 'chunks' of information to represent the configuration of pieces on a chessboard.

Another example of the context-sensitivity of expertise is provided by the mathematical activity used in the television programme 'Countdown'. The contestants are given a set of numbers, and, by using the four arithmetic operations of addition, subtraction, multiplication and division, are required to generate an arithmetical expression to the value of a given target number. For example, the given numbers might be 20, 11, 2, 5 and 3, with a target number of 105. There are many relatively general strategies that can be developed for solving problems such as these, but the most interesting feature of such problems for the purposes of this paper is that expert performance does not appear to use such general strategies. In fact most people use surprisingly specialized strategies that only work with the specific constraints and affordances (Gibson, 1979) of this particular problem. A typical approach relies on working forwards from the givens and backwards from the goal *at the same time*. It is important to note that this does not appear to be an iterative process, but rather, for most people with a reasonable repertoire of number facts, the fact that 5x20 is 100, which is close to the target number, seems to leap unbidden into consciousness.

Returning to the case of teaching, the research undertaken by Bennett, Desforges, Cockburn and Wilkinson (1984) found that teachers interpreted the information with which they were presented in classrooms in the light of their past experiences, and these 'filters' proved relatively difficult to modify. In terms of the arguments presented here, we can interpret this as the result of unconscious processing of sense data prior to their referral to conscious perception. The relative stability of the teachers' filters even in the face of a teacher's conscious desire to focus on a particular aspect of their behaviour which they wish to modify is not surprising because the filter has done its work in advance of the referral of sense data to consciousness. Even with the best will in the world, if consciousness doesn't actually get the data, it is impossible for it to act on them. In other words, inexpert teachers were simply unable to 'read' their classrooms in the same way as an expert might. Support for this interpretation comes from the work of David Berliner and his colleagues (see, for example, Berliner, Stein, Saberrs, Brown Claridge, Cushing, &

Pinnegar, 1989) who found that expert teachers had much richer interpretations of slides and videotapes of teaching situations, even though they could not say why they believed what they did. Perhaps most interestingly, expert teachers found situations in which actors played the roles of students much more disorienting than novice teachers although they were unable to articulate why. They appeared to rely on cues and signals that are processed unconsciously, but which actors playing the role of students did not reproduce.

From this it appears that there are no ‘shortcuts’ to teaching expertise. Expertise in teaching, as in most other areas, requires the development of the facility for unconscious processing of richly detailed data, from which the relevant details are abstracted and referred to consciousness. Furthermore, the pace of classroom activity means that there is literally no time to think (at least consciously). If we are to effect real and lasting improvements in teachers’ competence, we need a much more detailed of understanding of how different teachers, exposed to similar experiences develop such different filters in their unconscious processing.

**Assessment**

In assessment, there is a considerable debate over the use of analytic versus holistic marking schemes (Mabry, 1999; Wiliam, 1996; 1999). Concerns for inter-rater reliability have driven educational policy makers to implement assessment systems that attempt to define quality in terms of explicit criteria for success. This certainly has the effect of increasing the inter-rater reliability of the assessments (although relatively little work has been done in estimating the effects on other sorts of reliability).

However, there is widespread agreement that in many domains, particularly those that require creativity, and in the assessment of authentic performance, the imposition of such mark-schemes compromises validity. Where there is more than one correct answer, and where students can produce solutions not envisaged by the authors of the mark-scheme, high-quality responses can frequently be given low scores (Wiliam, 1998).

In terms of modern validity theory, this would be regarded as a kind of construct under-representation (Messick, 1989). Only some aspects of quality are represented in the mark-scheme, and other aspects are ignored. In terms of the arguments of this paper, however, we can interpret the mismatch between analytic and holistic scoring as a distinction between conscious and unconscious processing.

It is fairly clear that teachers acquire notions of ‘standards’ much more effectively when presented with actual samples of students’ work which exemplify the standards being promulgated than when given criterion-based descriptions of the standards. In the light of the research evidence presented above, I would like to suggest that the explanation of this phenomenon is that the grading of pieces of work with respect to a set of internal standards involves a far greater use of unconscious processing than has previously been acknowledged. Models that rely on the use of ‘grade descriptions’ within consciousness have insufficient bandwidth to capture the complexity of the processes involved. Ultimately, the perception of quality can never be an entirely conscious process. As Robert Pirsig has argued:

> Quality doesn’t have to be defined. You understand it without definition. Quality is a direct experience independent of and prior to intellectual abstractions. (Pirsig, 1991, p.64)

Again, a recognition and an understanding of the role of unconscious processing will be necessary before we can begin to develop teachers' ability to assess students' work reliably and fairly.

## Conclusion

The education systems of most developed countries are predicated on the assumption that the most valuable kind of knowledge is abstract, generalized and transcendent, and this assumption has been supported by the findings of mainstream psychology. Hyman Witkin, widely credited as the first to distinguish between field-dependence and field-independence (Witkin, 1950) has gone so far as to assert that field-independence—the ability to ignore contextual effects—*is* intelligence (Abelson, 1995, 182n). This has led to a search for broad general principles of expertise that can be used to 'short-cut' the learning process.

Now of course, general intellectual capability does clearly play a role in expertise of all kinds, but such capability will not lead to expertise if the right kinds of data are not available to conscious processing. The availability of these data requires a thorough grounding in experience which it appears is extraordinarily difficult to acquire without prolonged immersion in the relevant settings.

In the context of the research findings presented here the idea of intuition remains mysterious, but can be viewed as an exquisite and largely unconscious sensitivity to very small details. In the words of Andy Clark (1997), expertise can only be developed by 'being there'.

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**Note:**
An earlier version of this paper was presented at the annual conference of the European Educational Research Association, Lahti, Finland, September 1999.

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*Table 1: information flow in sensory systems and conscious perception*

| Sensory system | Total bandwidth (in bits/second) | Conscious bandwidth (in bits/second) |
|---|---|---|
| Eyes | 10,000,000 | 40 |
| Ears | 100,000 | 30 |
| Skin | 1,000,000 | 5 |
| Taste | 1,000 | 1 |
| Smell | 100,000 | 1 |

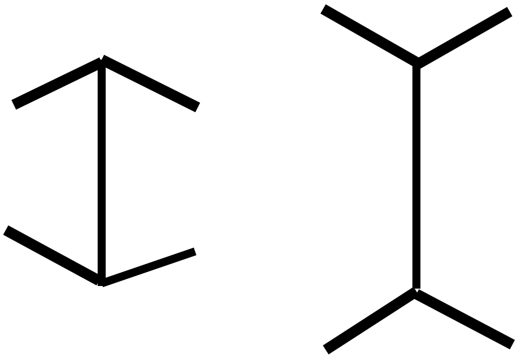

*Figure 1: the Müller-Lyer illusion*

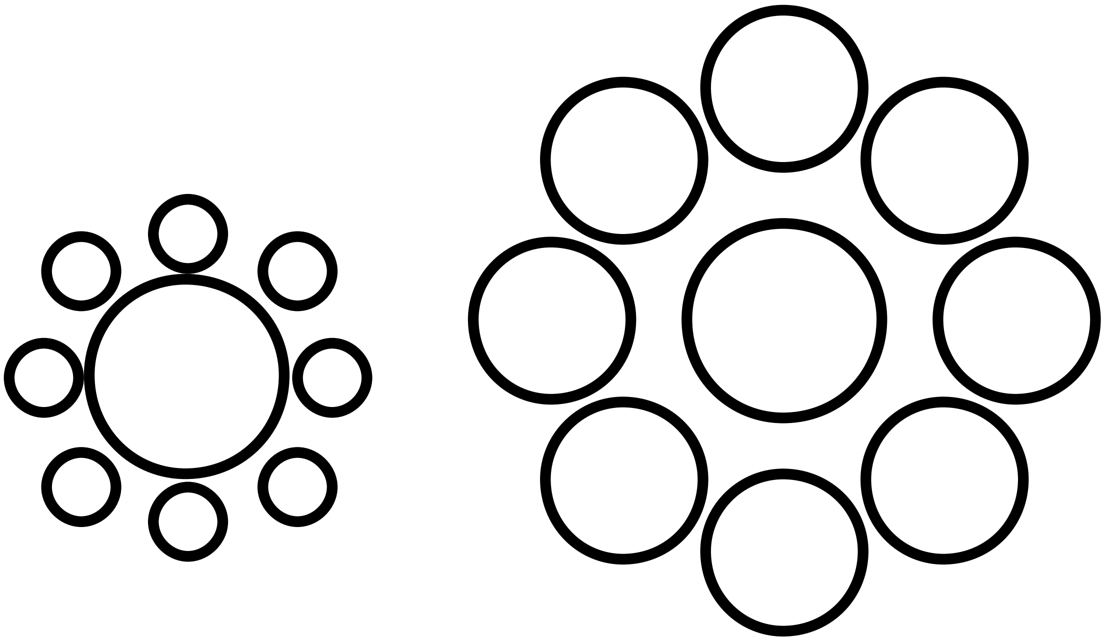

*Figure 2: an optical illusion that "deceives the eye but not the hand"*

*Table 2: performance in reconstructing actual and random chessboards*

| Position | Novices | Intermediates | Experts |
|---|---|---|---|
| Random | 4 | 3.5 | 3 |
| Actual | 4 | 8 | 16 |