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IS HUMAN INFORMATION PROCESSING CONSCIOUS?

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ABSTRACT: Investigations of the function of consciousness in human information processing have focused mainly on two questions: (1) where does consciousness enter into the information processing sequence and (2) how does conscious processing differ from preconscious and unconscious processing. Input analysis is thought to be initially "preconscious," "pre-attentive," fast, involuntary, and automatic. This is followed by "conscious," "focal-attentive" analysis which is relatively slow, voluntary, and flexible. It is thought that simple, familiar stimuli can be identified preconsciously, but conscious processing is needed to identify complex, novel stimuli. Conscious processing has also been thought to be necessary for choice, learning and memory, and the organization of complex, novel responses, particularly those requiring planning, reflection, or creativity.

The present target article reviews evidence that consciousness performs none of these functions. Consciousness nearly always results from focal-attentive processing (as a form of output) but does not itself enter into this or any other form of human information processing. This suggests that the term "conscious process" needs re-examination. Consciousness appears to be necessary in a variety of tasks because they require focal-attentive processing; if consciousness is absent, focal-attentive processing is

absent. From a first-person perspective, however, conscious states are causally effective. First-person accounts are complementary to third-person accounts. Although they can be translated into third-person accounts, they cannot be reduced to them.

In the words of George Miller (1987), "Consciousness is a word worn smooth by a million tongues". Its most common meanings are "awareness," "knowledge," and a "state of wakefulness." In the analysis that follows, it is "consciousness" in the sense of "awareness" that is of primary concern.

Much of human information processing seems to involve awareness (e.g. perception, imagery, and emotion). From a Darwinian standpoint, it is reasonable to assume that consciousness (in this sense) might have some function. Cognitive psychologists accordingly have devoted considerable effort to determining what the functions of consciousness might be.

This effort has focused mainly on two questions:

(1) Where does consciousness enter into human information processing?

(2) How does conscious processing differ from preconscious and unconscious processing?

The experimental literature dealing with these questions is both extensive and complex1, and there are many divergent theories2. Nonetheless, there is consensus on some points. Awareness of a stimulus is thought to be preceded by preconscious information processing. The physical features of well-learnt verbal stimuli, for example, are thought to be analyzed preconsciously (La Berge, 1975,1981; Posner, 1978; Shiffrin & schneider, 1977), in the first 250 msec. (Posner & Snyder, 1975; Neeley, 1977). Libet, Wright, Feinstein & Pearl (1979) review evidence that similar periods are required for preconscious processing of tactile stimuli - at least 200 msec. for suprathreshold stimuli, ranging up to 500 msec. for threshold stimuli. Suprathreshold stimuli applied to the skin, for example, are masked by electrical stimuli applied directly to the somatosensory cortex, up to 200 msec. after the skin stimuli have arrived at the cortical surface (a situation which could not arise if the skin stimuli had already entered awareness).

It is also thought that not all stimuli are selected for further "focal-attentive processing"; only those that enter consciousness (Broadbent, 1958; Mandler, 1985; Norman, 1969; Posner, 1978; Shiffrin & Schneider, 1977). The relationship between attention and consciousness is therefore a close one. Indeed, many psychologists explicitly or tacitly assume that "preconscious" processing is identical to "pre-attentive" processing, whereas "conscious" processing is identical to "focal-attentive" processing (e.g. Mandler, 1975,1985; Miller, 1987).

These assumptions are tempting. If they are justified, studies of "focal-attentive" processing become studies of "conscious" processing by definition. And "focal-attentive" processing, unlike "awareness," is easily understood in information processing terms. In the present target article, however, I do not take these assumptions for granted.

In the psychological literature, experimental investigations of the role of consciousness in human information processing have dealt largely with input analysis. Currently, "preconscious," "pre-attentive" analysis is thought to be involuntary, inflexible and automatic, and restricted to accessing the memory traces of simple, well-known stimuli. Conscious, focal-attentive processing is thought to be voluntary and flexible, and therefore required for the analysis of novel stimuli or novel stimulus arrangements. In sections 1.1 to 1.4 we examine the evidence for this view.

In sections 2.1 to 2.5 I develop an alternative view, citing evidence that preconscious analysis may extend to (novel) phrases and sentences and that consciousness of such material arises only after input analysis is complete. In sections 3 to 8, I question the many other ways consciousness has been claimed to enter into information processing, for example, in stimulus selection (following stimulus analysis), in learning and memory, and in the control of responses, including planning and creativity. I also re-examine the relationship of awareness to focal-attentive processing. Finally, in sections 9.1 to 9.3, we look more closely at what is meant by a "conscious process" and consider what the experimental studies of "conscious processing" imply, both for models of human information processing and for philosophy of mind.

1. Preconscious vs. conscious analysis of input stimuli.

1.1 Early studies of preconscious stimulus analysis, using a shadowing task.

Many early explorations of pre-attentive analysis used a "shadowing task," in which one message is presented through headphones to a subject's left ear while a different message is simultaneously presented to the subject's right ear. The subject is asked to attend to only one of the messages and to repeat aloud what he hears. Afterwards, however, he is questioned about the nonselected message3. Cherry (1953), for example, found that if subjects shadowed the message presented to one ear they were unable to report the meaning of the message in the other ear, or even be sure that it was in English, though they could report some of its physical characteristics. Subjects always noticed, for example, whether the nonselected message was in a male or a female voice, or whether it was speech or a 400 Hz tone. If the nonselected message was played backwards (on tape), they sometimes noticed that the reversed speech was "queer." Cherry concluded that certain physical and statistical properties of the nonselected message were analyzed but not its meaning.

On the basis of this and other evidence, Broadbent (1958) proposed the existence of a "bottleneck" in the human information processing system. The physical properties of the many stimuli arriving at the sense organs are simultaneously analyzed (in parallel "channels") in an automatic, preconscious fashion. However, the channel used for the analysis of meaning, has a limited capacity. Consequently, stimuli do not receive an analysis for meaning unless they are fully attended to (i.e., selected for entry into this "limited capacity decision channel") and it is only if they receive full (focal) attention that they enter consciousness, in which case they can be reported.

Further evidence of the inability to report words outside the focus of attention was provided by Moray (1959), who presented English words up to 35 times in the nonselected ear while words were shadowed in the other ear and found that subjects were unable to recall the nonselected words even though they knew they would be asked to recall them at the end of the shadowing task.

Some additional findings, however, indicated a more extensive analysis of nonselected input than that revealed by subjects' reports. Although they could report little about the nonselected messages, if those messages were preceded by the subjects' own names, they switched attention to them on 51% of the trials (Moray, 1959). Similarly, Treisman (1960) found that if the message in a shadowing task was suddenly switched from the shadowed ear to the nonselected ear, subjects made a corresponding (albeit temporary) switch in what they shadowed on 6% of the trials.

Thus, a pertinent stimulus, outside the focus of attention, can attract attention. But if preconscious analysis is restricted to the physical properties of a stimulus, how can this be? As Norman (1969) pointed out, if we could not determine the significance of stimuli outside the focus of attention it would be difficult to know when we needed to switch attention to them. In any case, the fact that a subject cannot report a message he has been specifically instructed to ignore (during shadowing) does not guarantee that he has not analyzed it.

1.2 Preconscious semantic analysis outside the focus of attention.

Later studies accordingly examined the analysis of stimuli outside the focus of attention by the subtler technique of assessing their influence on the attended message. Lewis (1970) found that the speed at which attended-to words were shadowed was influenced by the presence of semantically related words in the nonselected ear, but not by the presence of unrelated words. Corteen and Wood (1972) found that words previously associated with electric shocks continued to produce changes in galvanic skin response even when presented to the nonselected ear in a shadowing task, and that this occurred also with words which were semantically related to the conditioned word. Similar findings have been obtained by Corteen and Dunn, 1974; Forster & Govier, 1978; Von Wright, Anderson & Stenman, 1975; but not by Wardlaw & Kroll, 1976. Mackay (1973), furthermore, found that disambiguating words presented to the nonselected ear tended to bias the meanings of ambiguous, shadowed sentences in the attended ear.

Such studies have often been cited as evidence that under some circumstances the preconscious processing of stimuli outside the focus of attention includes the analysis of meaning. Indirect effects of the kind mentioned above, however, appear to be sensitive to small perturbations in experimental design. Consequently, in recent years the interpretation of these studies has become controversial (see Holender, 1986).

The Lewis (1970) study, for example, was repeated by Treisman, Squire & Green (1974), using a list of 10 dichotically presented word pairs. They replicated Lewis's findings for related pairs when these occurred early in the list (position 3) but not when they occurred later in the list (position 7). This may indicate that when subjects are accustomed to the shadowing task they no longer analyze the nonselected message, in which case Lewis's findings may have resulted from subjects, unaccustomed to shadowing, switching their focal attention to the nonselected ear. Alternatively, it may be that once subjects are accustomed to the shadowing task, their speed of responding to shadowed words is no longer influenced by the results of analyses that continue to take place on the nonselected ear.

The various replications of Corteen & Wood's (1972) study indicate that their results are reliable. However, the findings are subject to more than one interpretation. Dawson & Schell (1982), in a similar study, found that if subjects were told beforehand that they would be required to name the conditioned word in the nonselected ear, they could sometimes (but not always) do so. According to Holender (1986), this suggests that subjects had been momentarily aware of the nonselected, conditioned words in the earlier studies - a possibility admitted by Corteen (1986). Dawson & Schell's procedure, however, required subjects to divide their attention. It is therefore not strictly comparable to earlier studies where subjects were simply asked to shadow the message in the attended ear. Nevertheless, their finding highlights the difficulty of assessing the awareness of nonselected words in dichotic listening studies.

Mackay's (1973) finding that single, concurrent words in the nonselected ear disambiguated sentences in the selected ear was replicated by Newstead & Dennis (1979). However, if the critical words were embedded in sentences, the disambiguating effect did not occur. Again, according to Holender (1986), this implies that isolated words in the nonselected ear momentarily attract attention, leading to focal-attentive switching and conscious identification - an effect which does not occur if the words form part of a relatively continuous stimulus presented to the nonselected ear. Holender accordingly argues that such findings do not demonstrate semantic analysis without conscious identification.

It seems unlikely, however, that focal-attentive switching can account for the findings of Groeger (1984a,1984b). Groeger examined the effects of threshold words (presented to nonselected channels) on attended messages and found these to differ from the effects of the same words (similarly presented) at subthreshold levels. In one study, subjects were asked to complete sentences in the attended ear such as "She looked ---- in her new coat," with one of two completion words, e.g. "smug" or "cosy." Simultaneous with the attended sentence, the word "snug" was presented to the nonselected ear either at threshold or at various subthreshold levels. With "snug" presented at threshold level, subjects tended to choose "smug" as the completion word, indicating that they had some awareness of the physical structure of the cue. Below threshold, however, subjects tended to choose "cosy" as the completion word, which indicates semantic analysis (of the cue) without awareness.

One cannot assume from the findings above that semantic analysis of nonselected messages always takes place in dichotic listening studies, or that when it does, it makes no demand on limited processing resources (see section 2.4). Moreover, in dichotic listening studies it is often difficult to be certain that subjects have no awareness of stimuli presented to the nonselected ear. Nevertheless, such studies have produced diverse evidence of semantic analysis of nonselected words, under conditions where subjects claim to have no awareness of those words and are unable to report them afterwards. This suggests that under some circumstances a preliminary analysis for meaning can take place outside the focus of attention, without reportable consciousness.

But, if this is so, what are the limits of preconscious, nonfocal-attentive analysis? Even if one assumes that under some circumstances input stimuli not at the focus of attention receive an initial, preconscious analysis for meaning, there must be some limits on the processing of such stimuli, for there are limits on the tasks one can perform with them. In any case, only some of these stimuli actually enter consciousness.

1.3 A "two-process" theory of preconscious vs. conscious input analysis.

In the "late-selection" model of attention proposed by Posner and Boies (1971), simultaneous processing of input stimuli in different channels proceeds in a parallel, automatic, preconscious fashion, without mutual interference, up to the point where each stimulus is identified. This matches each stimulus to its long-term memory trace, which includes information relating to meaning (see also Norman, 1969; Posner, 1978; Shiffrin & Schneider, 1977). Processing above and beyond this (e.g. rehearsing an item, or choosing an appropriate output response to it) requires a limited capacity central processor, and only information that makes use of this processor enters consciousness. Indeed, Posner & Warren (1972) suggest that the use of the limited capacity central processor "becomes the central definition of a conscious process and its non-use is what is meant by a process being automatic."

By virtue of its limited capacity, information in this processor can only be processed in serial fashion and is susceptible to interference from other, competing tasks. Posner & Warren accordingly argue that susceptibility to interference provides one way of ascertaining which processes are conscious by experimental means (see Posner & Klein, 1973).

Posner and Snyder (1975) developed this "two-process" view in somewhat greater detail. Drawing on a theory proposed by Collins and Quillian (1969), they suggested that preconscious, pre-attentive processing produces a fast, automatic, "spreading activation" in the central nervous system (a parallel process). This activates not only memory traces of a given stimulus word but also related traces that share some of its features. However, this process has no effect on unrelated traces.

Limited capacity central processing, by contrast, only occurs after such spreading activation; it is relatively slow and serial in nature, and cannot operate without intention and awareness. Awareness that a given stimulus has been presented creates expectations about which stimuli are likely to follow and which stimuli are unlikely or unexpected.

In short, the processing of a given stimulus may affect the processing of subsequent stimuli. Meyer, Schvaneveldt & Ruddy (1975), for example, found that processing a given word may "prime" (facilitate) the recognition of a subsequent, semantically related target word. In a task where subjects had to decide whether a given string of letters was a word or a nonword, subjects responded to a word more quickly if the immediately preceding string was a semantically related word than if it was a nonrelated word. For example, reaction time to "nurse" is faster if it is preceded by the word "doctor" than if it is preceded by the word "bread."

According to the "two-process" view, the effects of such "lexical priming" are complex. If the target follows the prime within 250 msec. or less, conscious processing has insufficient time to operate. Spreading activation should facilitate the recognition of target words semantically related to the prime, producing faster recognition times, while recognition times for words unrelated to the prime remain unaffected. If the interval between target and prime increases beyond 250 msec., conscious processing also operates and expectations about future target words have time to develop. These should speed the recognition of expected target words but slow the recognition of unexpected words. The effects of "lexical priming," therefore, depend on (a) the interval between the prime and target word (b) the semantic relatedness between the prime and target word and (c) whether the subject, having perceived the prime, expects the target word.

These rather complex effects were investigated by Neeley (1977) using a "lexical priming" task similar to that devised by Meyer, Schvaneveldt & Ruddy (1975). As expected, priming words decreased the reaction time to related target words (e.g. bird -> robin) at short interstimulus intervals (250 msec.) but had no effect on the reaction time to unrelated target words (e.g. bird -> arm). Nor, at short interstimulus intervals, did subjects' expectations about likely target words have any effect. However, as the interval between the prime and target words increased from 250 msec. to 750 msec., reaction time to expected target words decreased progressively, whereas reaction time to unexpected target words progressively increased.

Neeley then introduced an experimental condition which appeared to clearly dissociate the effects of preconscious spreading activation from those of conscious expectation. In this condition, subjects were told to expect words that were semantically unrelated to the prime. Given the prime "body," for example, they were told to expect a target word relating to a "building" (such as "door"). At short interstimulus intervals (250 msec.) conscious expectations did not have time to operate, and as one would predict if spreading activation were operating in isolation, the prime "body" had no effect on the reaction time to these semantically unrelated target words. At longer interstimulus intervals, however, conscious expectations did appear to have an influence. As the interstimulus interval increased, the reaction time to the expected (but semantically unrelated) target words progressively decreased.

A similar dissociation was produced by giving subjects a target word that was semantically related to the prime under these conditions. For example, the prime "body," might be followed by the target word "heart" (which is semantically related to the prime) although subjects were expecting a target word relating to "building." In this situation, spreading activation from the prime "body" appeared to facilitate the recognition of the semantically related word "heart," speeding the reaction time to the target by around 40 msec. (at 250 msec. interstimulus intervals). At longer interstimulus intervals, however, the expectation of a target word relating to "building" appeared to progressively inhibit recognition of the word "heart" (i.e. to oppose the effects of spreading activation); so at 750 msec. intervals, reaction time to the unexpected target word was around 40 msec. slower than normal.

Neeley concluded that his findings provide strong support for Posner and Snyder's "two-process" theory; an initial preconscious identification process accesses not only the memory traces of the input stimulus but also those of semantically related stimuli; this is followed by a conscious identification process that not only facilitates the recognition of expected stimuli but also inhibits the recognition of unexpected stimuli (but see Underwood, 1977).

1.4 Current ways of distinguishing preconscious from conscious input analysis.

In recent years, theories of how attentional resources are devoted to input analysis have continued to develop. La Berge (1981) and Kahneman & Treisman (1984), for example, review evidence that the processing of visual stimuli which are not at the focus of attention may, to varying degrees, demand attentional resources (see section 2.4) - a finding similar to that obtained with acoustic stimuli in dichotic listening studies, but inconsistent with "late selection" theories.4

There is also reason to believe that different forms of attention may have to be devoted to different stages of input analysis. La Berge (1981), for example, suggests that attention has to be devoted to physical features in the process of searching for a target input stimulus, and both La Berge (1981) and Kahneman & Treisman (1984) propose that attentional resources may be needed to integrate the set of features at the location found by the search. Kahneman & Treisman (1984) go on to suggest that some attentional limits may turn out to be failures in the dissemination of the results of input analysis to other information processing modules rather than failures in input processing itself.

Kahneman & Treisman (1984) note, however, that the question of how attentional resources are allocated is in principle distinguishable from the question of what is or is not conscious.5 For present purposes, the latter distinction is the crucial one.

As should be apparent from the foregoing review, there is considerable disagreement about how the distinction between preconscious and conscious analysis should be framed. It seems clear, however, that consciousness of an input occurs relatively late in the information processing sequence. It also appears that words in both nonselected and attended channels can be analyzed for meaning in the absence of any ability to report them; this indicates that semantic analysis is possible without consciousness.6

According to current theory, "preconscious" analysis nevertheless differs from "conscious" analysis. For example, if Posner & Snyder (1975) and Neeley (1977) are right, "preconscious" analysis activates memory traces of input stimuli and traces of semantically related stimuli, but has no effect on traces of unrelated stimuli. By contrast, "conscious" analysis both facilitates the activation of semantically related stimuli and inhibits the activation of unrelated stimuli. The above findings also appear to be consistent with the view that "preconscious" analysis is fast and automatic in the sense of being involuntary and inflexible (but not automatic in the sense of being free of processing capacity restraints) -whereas "conscious" analysis is relatively slow, flexible and voluntary. Preconscious analysis is accordingly thought to be both rudimentary and limited (Posner and Snyder, 1975; Bjork, 1975; Underwood, 1979). Bjork, for example, asserts that without the involvement of the conscious central processor, "nothing happens in the system beyond the formation of input traces." If this were true, conscious analysis would play a crucial role in the adaptive activities of the brain for it would be required for the processing of any novel stimulus (i.e., any stimulus that did not already have a long-term memory trace) and for the processing of novel stimulus arrangements. For example, preconscious analysis might suffice to identify the meanings of well-known individual words, but conscious analysis would be required to identify the complex meanings of novel phrases and sentences. This is not supported by the evidence, however.

2. Does consciousness enter into input analysis?

2.1 Preconscious analysis of complex messages outside the focus of attention.

Evidence that phrases and sentences can be analyzed outside the focus of attention has been found by Treisman (1964a). In one experiment, she asked subjects who were bilingual in English and French to shadow passages of English prose presented to one ear in a female voice. Simultaneously, a different prose passage in English, French, German, Czech, reversed English, and a French translation of the shadowed message, were presented to the other ear in a male voice. Treisman found that subjects always noticed the male voice (replicating Cherry, 1953). In addition, however, just under half the subjects recognised the French translation. Treisman concluded that the physical characteristics of the voice in the nonselected ear were always analyzed, but the meaning of the prose passage in the nonselected ear was not always fully analyzed.

On the other hand, many subjects did recognise the meaning of the French translation, indicating that preconscious analysis of connected prose is possible outside the focus of attention. Indeed, in another experiment Treisman (1964b) found that the better the subject knew the language in the nonselected ear, the more difficult it was to reject. Whereas monolingual subjects could easily shadow the English prose passage, bilinguals found the task more difficult, often giving a response in mixed English and French.

As Holender (1986) notes, shadowing tasks are very attention demanding, so it is unlikely that subjects in this task voluntarily switched their attention to a (continuous) message in the nonselected ear, which they had been instructed to ignore. It would seem, therefore, that complex messages can be analyzed outside the focus of attention (preconsciously) although there are individual differences in the extent to which this is normally done, depending on how skilled subjects are at identifying the nonselected input.

Further evidence of preconscious analysis of complex, nonselected messages was found by Lackner and Garrett (1973), who presented ambiguous sentences to one "attended" ear, while disambiguating sentences were presented, simultaneously, to the subject's other ear. For example, if "Visiting relatives can be a bore," was the attended sentence, it might be paired with "I hate relatives who visit often," in the nonselected ear. Subjects were asked to paraphrase each attended-to sentence immediately (if possible, before it ended).

The sentences in the nonselected ear were presented at intensity levels 5 to 10 dB below those of the attended sentences and subjects could produce no systematic information about them. Nevertheless, the meanings of nonselected sentences biased subjects' paraphrases of sentences in the attended ear. In the situation above, for example, the attended sentence tended to be paraphrased as, "Relatives who visit can be boring," rather than, "It can be boring to visit relatives."

According to Lackner and Garrett, at least a phrasal analysis of nonselected sentences would have been required (in most of the material they used) to disambiguate the meaning of the attended sentences; for example, in the non attended sentence above, at least "relatives who visit" would have had to be analyzed. Holender (1986) goes further, pointing out that disambiguation occurred even if the disambiguating portion of the nonselected sentence followed the ambiguous portion of the relevant sentence. This implies that a complete syntactic and semantic analysis of the nonselected sentence took place. Moreover, the product of this analysis had to be integrated with the analysis of the attended sentence in order to yield a particular interpretation of it - a task demanding considerable processing resources.

One can go further still. Although human speech perception is not yet fully understood, the processes involved are thought to be both "productive" (indefinitely novel) and complex - so complex, in fact, that they surpass the capabilities of the most sophisticated present-day machines. According to current theory, speech perception involves various levels of analysis (phonemic, syntactic and semantic) interacting in a dynamic, flexible, interactive fashion, incorporating both "data-driven" and "cognitively driven" processing (see section 2.3). If this is so, the analysis of nonselected spoken phrases and sentences is unlikely to be restricted to inflexible, "data-driven" processing.7

The findings of Treisman (1964a;1964b) and Lackner & Garrett (1973) demonstrate that the analysis of messages outside the focus of attention can extend to spoken phrases and sentences, involving syntactic and semantic analysis of potentially novel word combinations. If so, preconscious, nonfocal-attentive analysis cannot be restricted to a relatively inflexible, data-driven analysis of simple, well-learnt stimuli. It is therefore misleading to think of the processing of stimuli in the nonselected ear as nonattended or even as pre-attentive in dichotic listening tasks of the kind described above. Even when subjects are instructed to shadow or paraphrase a message in one ear and ignore the message in the other ear, the nonselected message may be subject to sophisticated analysis. In this sense, the rejected message is receiving attentional resources (allocated to input analysis), although it may not enter consciousness, alter long-term memory or be available as a response. In short, rather than speaking of "pre-attentive" processing (versus "focal-attentive" processing) in such divided attention tasks, it seems more accurate to speak of "preliminary attention" (versus "focal attention") - a suggestion consistent with the "filter" model of selective attention advocated by Treisman and her associates (reviewed in Kahneman & Treisman, 1984).

Once relabelled, the "preliminary attention"/"focal attention" distinction remains a useful one. Stimuli that are preconsciously analyzed, identified and then ignored, for example, appear to be treated differently from stimuli that are selected for focal-attentive processing and subsequently enter consciousness. It remains possible, furthermore, that once stimuli are at the focus of attention, they are analyzed in a different, "conscious" way.

2.2 Preconscious semantic analysis in the attended channel.

In psychological tasks, the "attended" channel is operationally defined by combining instructions to subjects to attend in a given way with appropriate forms of stimulus presentation. For example, the subject might be asked to focus on material in one ear rather than the other, or to fixate a particular point on a screen, and then the stimulus is presented to the point of focus. In the current literature, the analysis of stimuli in nonselected channels is thought to be "preconscious" and the analysis of stimuli in the attended channel is thought to be "conscious."

It has to be borne in mind, however, that most models of selective attention assume that input stimuli receive some initial, preconscious analysis (preliminary attention) whether or not they are in the attended channel. This applies to both early-selection models (e.g. Broadbent, 1958) and late-selection models (e.g. the "two-process" model of Posner & Snyder, 1975, discussed above). Stimuli in the attended channel differ in that they are normally selected for further "focal-attentive processing" and it is only when this happens that they enter consciousness. In principle, therefore, it might be possible for input in an attended channel to be preconsciously analyzed without being subject to "conscious" focal-attentive analysis - for example, if the input is "masked" before it can be fully analyzed, as in the studies of "masked priming" discussed below.

In the "priming" studies of Schvaneveldt, et al.(1975) and Neeley (1977), both the prime and the target are presented suprathreshold and both are potentially available to consciousness. But in "masked priming" studies the prime is followed by a masking stimulus, and at certain prime-mask intervals this prevents the prime from entering consciousness (according to subjective reports). It may nevertheless continue to influence the subject's response to the following target, providing evidence for at least some analysis (of the prime) in the absence of reportable consciousness.

As with the dichotic listening studies discussed above, the effects of masked priming appear to be extremely sensitive to small perturbations in experimental design, producing extensive discussion in the literature of methodological issues, and controversy over the reliability and interpretation of experimental results.8 For example, Holender (1986) reviews evidence that when masked priming effects occur, subjects remain able to make judgements about the prime (via some form of discriminative response) despite their claim not to have seen it - evidence, he argues, that introspective reports of whether or not the prime enters consciousness are unreliable (see also Lupker, 1986).

Cheesman & Merikle (1986) agree that the prime-mask interval at which subjects claim they cannot see the prime (the "subjective" threshold) must be distinguished from the shorter interval at which subjects cannot make a better than chance judgement about the prime (the "objective" threshold). Contrary to Holender's interpretation, however, they point out that it is the "subjective" threshold rather than the ability to make a discriminative response that relates directly to what is consciously experienced. They also suggest that if a prime presented above the subjective threshold has a qualitatively different effect from one presented below that threshold, this would provide strong support for the claim that the subjective threshold defines the transition between two different perceptual states (i.e. between perceptual processing which is accompanied by consciousness and processing which is not; see also discussion of Groeger, 1984b, above).

Such effects have been demonstrated by Cheesman & Merikle (1984,1986), Dagenbach, et al.(1989), Forster & Davis (1984), and Marcel (1980, 1983 experiment 5). Marcel (1980), for example, used polysemous primes (with multiple meanings) embedded within three word sequences, each beginning with a context word followed by the polysemous prime, and ending with a target (for example, "save - bank - money," or "save - bank - river"). In one condition, the primes were presented unmasked, at an exposure duration of 500 msec. In this suprathreshold condition, selective priming of the target occurred; for example, in the above three word sequences, the cued meaning of the prime "bank" facilitated the response to the target "money," but not "river." In the other condition, the primes were presented for 10 msec. and followed by a pattern mask at an interval set to produce chance detection of the prime. With masked primes, unselective priming occurred; for example, in the above sequences, the word "bank" primed both "money" and "river." These findings indicate that semantic analysis of familiar stimuli in the attended channel can take place without reportable consciousness. Hence, consciousness cannot be necessary for such analysis. At the same time, processing which is accompanied by awareness (of the stimulus) appears to differ from processing which is not accompanied by awareness. Marcel's findings, for example, appear to support Posner & Snyder's "two-process" theory. They suggest that when a polysemous word in the attended channel is first analyzed, simultaneous activation of its multiple meanings takes place preconsciously. Once focal-attentive processing operates, one meaning is selected and the subsequent entry of the word into consciousness is accompanied by inhibition (or deactivation) of inappropriate meanings. Similar effects have also been observed with polysemous words in connected speech (Pynte, Do & Scampa, 1984; Swinney, 1979, 1982).

Masked priming studies, however, do not enable one to dissociate entry into consciousness from the effects of focal-attentive processing. Masking that prevents entry into consciousness is also likely to disrupt focal-attentive processing. The different effects of primes above and below the "subjective" threshold may therefore be due not to entry into consciousness as such, but to the operation (or nonoperation) of focal-attentive processing.9

Such studies do demonstrate that the identification of well-known stimulus words in the attended channel is initially preconscious. Moreover, there is evidence from studies of speech perception that even if awareness does accompany input analysis (of connected speech in the attended channel), that awareness follows input analysis and consequently cannot enter into it.

2.3 Preconscious analysis of complex messages in the attended channel.

Marslen-Wilson (1984) reviews evidence that the analysis of words in attended-to connected speech is both "data-driven" and "cognitively driven," combining knowledge of the stimulus with knowledge of its context. For example, in Grosjean's (1980) word recognition task, successively larger fragments of a word were presented. If the words were presented in isolation, subjects required fragments of 333 msec. (on average) to identify them (total word length was in excess of 400 msec.). But if the words were presented in normal verbal contexts, a fragment of 199 msec. (on average) was sufficient to identify them. In a related experiment, Marslen-Wilson and Tyler (1980) found that the average reaction time to detect target words (in context) was 273 msec., although their mean length was 370 msec. Allowing around 75 msec. execution time (the time to press a button) this again suggests a word identification time of around 200 msec.

Now, a word fragment of 200 msec. is large enough to contain just the first two phonemes and, according to Marslen-Wilson (1984), these convey useful information. Assuming a dictionary of 20,000 American-English words, knowledge of the first phoneme reduces the set of possible words to a median of 1,033, knowledge of the first two phonemes reduces the set size to a median of 87, and so on (Kucera and Francis, 1967). In this way, sensory analysis (a largely "data-driven" process) contributes to word identification. After two phonemes, however, a large number of possible words remain (a median of 87). Hence subjects who can identify the word on the basis of the first two phonemes must use their knowledge of the context to decide which of the remaining words is the correct one (a "cognitively driven" process).

On the basis of this and other evidence Marslen-Wilson (1984) concludes that to cope with a complex acoustic waveform developing over time the speech processing system moves the analysis of the sensory signal as rapidly as possible to a domain where all possible sources of information (semantic as well as phonemic) can be brought to bear on its further analysis and interpretation - a process of "on-line interactive analysis" of considerable sophistication and flexibility.

The stimuli to be identified in these experiments are in the attended channel. Yet if words (in context) are identified within 200 msec., this confluence of data-driven and cognitively driven processing cannot be conscious, for according to the evidence reviewed earlier (Libet, et al., 1979; Posner and Snyder, 1975; Neeley, 1977), consciousness of a given stimulus does not arise until at least 200 msec. after the stimulus arrives at the cortical projection areas, i.e. after the identification of a word (in context) has been achieved!

In these experiments spoken words in the attended channel are therefore analyzed in preconscious fashion. Indeed, it is by no means clear that the analysis of words in the attended channel is different from the analysis of words in nonselected channels. In either case, pattern-recognition may be flexible and dynamic, combining data-driven and cognitively driven processing; and there seems to be little doubt that pattern recognition is preconscious in both cases.

Rather than consciousness entering into input analysis of well-known stimuli, consciousness of those stimuli appears to follow sophisticated, preconscious analysis and identification. If this is the case, "conscious" focal-attentive processing cannot be necessary for the analysis and identification of such stimuli even when they occur in novel, complex combinations. This may seem counterintuitive. It is, however, easy to illustrate. Consider how one silently reads the following sentence:

"The forest ranger did not permit us to enter the reserve without a permit."

Note that on its first occurrence, the word "permit" was (silently) pronounced with the stress on the second syllable (permit) while on its second occurrence the stress was on the first syllable (permit). But how did you know?

Clearly, the syntactic and semantic analysis required to determine the appropriate meaning of the word "permit" must have taken place prior to the allocation of the stress pattern; and this, in turn, must have taken place prior to the phonemic image entering awareness.

Note too, that while reading, one is not conscious of any pattern recognition processing to identify individual words or of any syntactic or semantic analysis being applied to the sentence. Nor is one aware of the processing responsible for the resulting covert speech (with the appropriate stress patterns on the word "permit"). In this case, not just an individual word, but an entire attended-to sentence appears to be processed in preconscious fashion.

2.4 Input analysis is largely involuntary.

Note finally that the analysis of well-known stimuli proceeds in a

largely involuntary fashion, whether or not the stimuli are in the attended channel. Even if one "consciously attends" to a given stimulus, it may be difficult to prevent certain analyses from being carried out; in this sense, the analysis is automatic.

This point was demonstrated by Stroop (1935), who observed that subjects instructed to name the colour in which a word is printed found the task far more difficult if the word was itself a colour name, but of a different colour. For example, subjects presented with the word "red" printed in orange cannot restrict their analysis to the colour of the print (orange) because they cannot prevent themselves from reading the word ("red"). Eventually, a subject may adopt some artificial strategy to avoid reading the word, for example, squinting to avoid seeing the letters. Even with extended practice, however, the task remains difficult (in comparison say, to naming colour patches, or simply reading a colour word - see Jensen, 1965).

On the basis of this and other evidence, Kahneman (1973) concludes that "subjects cannot prevent the perceptual analysis of irrelevant attributes of an attended object." Even if a stimulus is consciously attended to, what is analyzed may not be under conscious voluntary control. However, an "involuntary" process is not necessarily "inflexible" (see above).10 Nor need it be "effortless" (Regan, 1981). Recent studies of the Stroop effect indicate that while input analysis may be automatic in the sense of "involuntary," it nevertheless draws on limited processing resources (Kahneman & Treisman, 1984).

In one study, for example, Kahneman & Chajcyk (1983) found that subjects took longer to name the colour of a centrally fixated colour bar if a conflicting colour word was presented either above or below it. This "Stroop" effect was not as great as when subjects were asked to name the ink in which a conflicting colour word was printed, indicating that the effect depends, in part, on whether or not the conflicting information is spatially integrated with the fixated stimulus (see also Dyer, 1973; Gatti & Egeth, 1978). Kahneman & Chajcyk found the Stroop effect was further diluted by a neutral word, presented simultaneously with the conflicting colour word, to the opposite side of the bar. They accordingly conclude that the two irrelevant words were competing for limited processing resources.

Nevertheless, unless subjects have advance information about the precise location of the irrelevant information, they cannot avoid processing it (Kahneman & Treisman, 1984). Processing remains automatic in the sense of being outside conscious voluntary control - again calling into question the role of consciousness in input analysis.

2.5 Automatic, flexible, preconscious analysis of familiar input stimuli.

The evidence reviewed in sections 2.1 to 2.4 suggests that current ways of distinguishing "preconscious" from "conscious" analysis require re-examination. Conventionally, "preconscious," "pre-attentive" analysis is thought to be automatic (in the sense of being involuntary), and restricted to simple, familiar stimuli whose long-term memory traces are accessed in data-driven (albeit resource-limited) fashion. By contrast, "conscious," "focal-attentive" analysis is voluntary and flexible (involving cognitively-driven as well as data-driven processing).

If preconscious analysis (in nonselected channels) can deal with the syntactic and semantic analysis required to identify the meanings of phrases and sentences involving potentially novel word combinations, then it cannot be restricted to simple, familiar stimuli. The on-line analysis of speech is one of the most sophisticated of human pattern recognition tasks, involving both cognitively driven and data-driven processing. Hence, while preconscious analysis might be automatic (in the sense of being involuntary) it cannot be inflexible.

Input analysis of phrases and sentences in the attended channel appears to be similarly automatic (involuntary) and flexible. It is also largely preconscious, casting doubt on the assumption that input in the attended channel is subject to "conscious," "focal-attentive" analysis. Consciousness of familiar stimuli, rather than entering into input analysis, appears to follow it, in human information processing.

3. Preconscious selection and choice .

However, input analysis and identification are merely the first stages of human information processing. While many inputs may be simultaneously analyzed and identified preconsciously, only some receive our full focal attention. Those that do, need to be selected from competing stimuli according to their interest or importance. Perhaps, as Mandler (1975,1985) and Miller (1987) suggest, consciousness makes it possible to select and choose.

Consider how such selections are made. Prior to being selected for focal-attentive processing, input stimuli do not enter consciousness. The information on which such choices are based must therefore be represented in the CNS in preconscious fashion. What is important to attend to at any given moment also requires continuous updating, for in a constantly changing world, that which is of primary importance may itself be in continuous flux and change.

But are assessments of relative importance conscious? If so, it is odd that we are not normally aware of making them. Rather, the detailed operation of such selection procedures, still under investigation within cognitive psychology, can only be inferred.11

Carr & Bacharach (1976), for example, review evidence for the existence of preconscious input selection in the form of perceptual tuning of input analyzers by prior conceptual or structural stimulus information. Some of this tuning is long-term and is manifest, for example, in the characteristic tendency to analyze visual scenes in terms of conceptually meaningful relations among stimulus components. This process may be likened to a "parsing" of the scenes in accordance with a form of "visual grammar" (Biederman, 1972; Biederman, Glass & Stacey, 1973; Biederman, Rabinowitz, Glass & Stacey, 1974). Other tuning is temporary. Preconscious, semantic priming effects (discussed in sections 1.3 and 2.2) may be regarded as cases of this kind.

Hence, it is reasonable to assume that some selective processes are preconscious. This does not, of course, rule out the possibility of a subsequent "conscious voluntary choice" amongst stimuli which have been preconsciously selected for focal-attentive processing and which now require some response. Carr & Bacharach (1976) argue, for example, that input selection must be distinguished from task selection. Whereas input selection is preconscious, task selection is under conscious, voluntary control.

Yet, even a "conscious voluntary choice" may have preconscious neural antecedents. It has been known for some time that voluntary acts are preceded by a slow negative shift in electrical potential (recorded at the scalp) known as the "readiness potential," and that this shift can precede the act by up to one second or more (Deecke, Grozinger & Kornhuber, 1976; Gilden, Vaughan & Costa, 1966; Kornhuber & Deecke, 1965).

In itself, this says nothing about the relation of the readiness potential to the experienced wish to perform an act. To address this, Libet (1985) developed a procedure which enabled subjects to note the instant they experienced a wish to perform a specified act (a simple flexion of the wrist or fingers) by relating the onset of the experienced wish to the spatial position of a revolving spot on a clock face, thereby giving it a "clock time." Recorded in this way, the experienced wish (to flex the wrist or fingers) was preceded by a preconscious readiness potential by around 550 msec. (for spontaneous acts involving no preplanning).

This suggests that conscious volition may be one output from the (prior) cerebral processes that actually select a given response. Hence, conscious volition may be no more necessary for such a (preconscious) choice than the consciousness of a stimulus is necessary for the (prior) pattern recognition of that stimulus (see Libet, 1985 and accompanying BBS open peer commentary, and Harnad, 1982, for a more detailed discussion).

4. Consciousness, learning and memory.

4.1 Is consciousness necessary for learning?

The experiments above suggest that input analysis and selection can take place preconsciously. However, subjects in these experiments were required to process known stimuli, using well-established skills. To some extent, such "automaticity" needs to be acquired. Hence, consciousness may be essential when novel stimuli or skills are being learnt.

According to La Berge (1981), learning to identify simple patterns may involve different attentional processes. To identify a new pattern as a coherent unit may require one to combine outputs from various feature detectors to form an integrated, higher-order perceptual code. Attaching a name to a pattern or investing it with meaning may require one to form associations between relatively distinct representational systems (for example, associations between visual codes and phonemic or semantic codes). Such learning usually requires focal attention, and focal-attentive processing is usually accompanied by consciousness. However, consciousness of the input stimulus, of the associations being formed, and so forth, result from focal-attentive processing. The integration of feature analyzers into a higher order perceptual code, and the formation of associations between different cerebral representational systems, are processes to which we have no introspective access, which would normally be explained in entirely neurophysiological terms!

In his analysis of what the functions of consciousness might be, Baars (1989) agrees that its contribution to learning is a mystery. As he notes,

" To learn anything new we merely pay attention to it. Learning occurs "magically" - we merely allow ourselves to interact consciously with algebra, with language....etc., and somehow, without detailed conscious intervention, we acquire the relevant knowledge and skill. But we know that learning cannot be a simple, unitary process in its details...all forms of learning involve specialised components of knowledge and acquisition strategies."

Baars nevertheless concludes that consciousness (in some unspecified fashion) facilitates learning. All that one can infer from the above, however, is that focal-attentive processing facilitates learning. While consciousness accompanies such processing, the details of such processing are not under conscious control. Similar arguments apply, furthermore, if one thinks of "learning" in terms of the updating of (or transfer of information to) long-term memory.

4.2 Is consciousness necessary for encoding in long-term memory?

On intuitive grounds, it is difficult to envisage how, without consciousness, one could update long-term memory, for if one has never experienced an event, how could one remember it? - How could an event which is not part of one's psychological present become part of one's psychological past?

It is important to distinguish the contents of consciousness (which in the theories of James, 1890, and Waugh and Norman, 1965, are identified with the contents of "primary memory") and contents of long-term memory (or "secondary memory") from the processes which encode information, transfer it between primary and secondary memory, search for and retrieve it, and so on. Such processes are no more conscious (accessible to introspection) than are the other ones discussed above. Furthermore, preconscious contents may influence the way the contents of consciousness are interpreted and, consequently, remembered. In dichotic listening studies, for example, words and sentences in the nonselected ear may influence the interpretation of sentences in the attended ear (Lackner and Garrett, 1973; MacKay, 1973). But how about memory of the preconscious contents themselves? It is the accepted wisdom (backed by numerous experiments) that unless preconscious contents are selected for focal-attentive processing and enter consciousness, they are quickly lost from the system (within 30 seconds). Words and sentences presented to the nonselected ear in dichotic listening studies, for example, cannot usually be remembered.

It appears, however, that preconscious processing can affect the memory trace of an input stimulus even if that stimulus cannot later be explicitly recognised or recalled. Eich (1984), for example, required subjects to shadow a passage presented to one ear while word pairs were presented to the other ear. The second member of each pair was a homophone (a phoneme string corresponding to more than one word, e.g. FAIR, FARE), and the first member of each pair cued its less common usage (e.g. taxi - FARE). The shadowing task reduced recognition of the homophones to chance levels in a subsequent recognition test. Nevertheless, in a subsequent spelling test, subjects were more likely to produce the cued (less common) interpretation of the homophones. Moreover, recent studies of hypnosis (discussed below) indicate that information may be able to enter long-term memory and be recalled, without first entering consciousness.

4.3 The hidden observer.

In hypnotically induced anaesthesia subjects may report experiencing no pain, although they exhibit normal physiological responses to painful stimuli, that is, painful stimuli are processed by the central nervous system despite appearing to be neither experienced nor remembered. Under some circumstances, however, a "hidden observer" within the subject may be fully cognizant of what is going on (see Hilgard, 1986 and reviews in Kihlstrom, 1984; Oakley & Eames, 1985).

One way to elicit this phenomenon is to inform a subject, before hypnosis, that some part of him will continue to monitor everything that happens during hypnosis even if he is not aware of it. During hypnosis one can then ask to speak to this "hidden observer," in which case subjects frequently begin to speak and act as if they were no longer hypnotised (although they are still under hypnosis).

According to Oakley & Eames (1985),

"Two reports may thus be taken from a hypnotised subject. In hypnotic analgesia, for instance, it is possible for a subject to smile benignly and, despite physiological evidence to the contrary, to fail to experience pain in a hand which is plunged into icy water. The hidden observer, however, when called upon, leaves the experimenter in no doubt as to the severity of the pain in the affected hand and will give a pain rating, either verbally or in the form of 'automatic writing' with the nonimmersed hand, which matches that given in the waking state under the same conditions ..... The absence of pain is nonetheless real to the hypnotised subject. Transfer of a similar dissociation to the waking state is possible in some types of chronic pain, and therapies which aim to relegate pain to the hidden observer, by setting up selective mechanisms in consciousness which deny pain information entry into self-awareness, are successful in a proportion of individuals.... Some hypnotic subjects are able to achieve, upon suggestion, a level of anaesthesia and local analgesia sufficient to allow painful surgical procedures to be carried out without apparent discomfort or distress, and often with reduced bleeding and salivation. In these subjects physiological indices of pain may also be absent ....One hypnotised subject, Mrs D., underwent an operation to remove a ganglion in her left wrist and a foreign body in her right index finger. In a later interview, also under hypnosis, she was able to recall the people in the operating theatre, the numbness in her arms and the fact that she had asked for, and been given, a drink of water during the operation. During the surgical procedures, she had thought mainly of a holiday, and had experienced the sun shining as she sailed in a pedal-craft. She had known that the operation was taking place but had felt nothing of it. A suggestion designed to call the hidden observer, however, produced a different story. The thermocautery was 'so hot...It was burning...it was agony...as bad as the incision' ." (p240)

The hidden observer phenomenon has been replicated on many occasions (see reviews cited above). According to some investigators, however, the phenomenon arises from subjects' attempts to comply with what is demanded of them under hypnosis instructions, rather than from any special hypnotised state (Spanos, 1986, 1988; Wagstaff, 1981,1987). Spanos & Hewitt (1980), for example, exposed highly suggestible hypnotic subjects in one experimental group to the same procedures used by Hilgard & Hilgard (1975) for eliciting hidden reports (suggesting that the hidden observer would remain aware of what was going on) and replicated the finding that the hidden observer felt high levels of pain, although overtly, the hypnotised subject experienced reduced pain. However, a second highly suggestible group were told that their hidden part was hidden so deeply that it would be even less aware of what was being experienced than their overt part - and these hidden observers, correspondingly, reported lower levels of pain than the overt pain.

As Spanos (1986) notes, this in itself may merely indicate that different suggestions produce different amounts of dissociation from the pain experience. Spanos, Gwynn & Stam (1983) however, found that if a given subject received no prior indication of how much pain the hidden observer should feel, he could be made to report greater, less, or the same hidden pain (relative to the overt pain) if he were sequentially exposed to instructions that explicitly called for each of these patterns of responding - a clear demonstration that hidden observer reports may be influenced by the demand characteristics of the experimental situation. Nogrady, McConkey, Laurence & Perry (1983), however, found that the proportion of hypnotised subjects who gave hidden observer reports was little influenced by whether or not there was pressure to produce such reports from the hypnotist, varying from around 42 per cent with little pressure to around 50 per cent with extreme pressure. By contrast, a group of subjects instructed to simulate hypnosis gave no hidden observer reports when under little pressure, but under extreme pressure the proportion giving such reports rose to 75 per cent.

Accordingly, it remains possible that genuine dissociation effects also occur. It seems unlikely, for example, that subjects undergoing surgery under hypnotic analgesia are simply lying about their lack of pain to please the medical staff! And comments from some hypnotised subjects indicate that they believe some inner dissociation to be taking place. Colman (1987) cites the case of a subject under hypnotic analgesia whose whole body moved when exposed to a normally painful electric shock. When questioned about this, she said, "I don't feel anything, but she seems uncomfortable" - even though no hidden observer instructions were given in this experiment (in Sutcliffe, 1961). Similar reports occurred in a hidden observer experiment by Knox, Morgan & Hilgard (1974). In the words of one subject, "The hidden observer is more aware and reported honestly what was there. The hypnotised part of me just wasn't aware of the pain" (see Bowers, 1976; Colman, 1987; for further discussion of this point). Whether hypnotism should be thought of as a special state, or some combination of social compliance (Spanos, 1986, 1988) with conventional coping strategies such as selective inattention, relaxation, etc. (Wagstaff, 1987) remains controversial. However, if subjects' hidden observer reports are to be believed, it is possible for painful stimuli to enter long-term (episodic) memory without first entering consciousness - evidence that entry into consciousness is not necessary for long-term memory updates.

4.4 Implicit learning and memory.

Much learning and memory has to do not with individual stimuli occurring in a single episode but with recurring stimulus patterns. On any given occasion, the stimuli themselves may be present to consciousness, but the fact that they form a recurring pattern may not. Being exposed to successive exemplars of recurring patterns, however, may produce learning of those patterns, whether or not there is any intention to learn and, indeed, in the absence of any explicit knowledge of the pattern being learnt. The evidence for this has been extensively reviewed by Schacter (1987) and Reber (1989), and we need not recount it here. One series of experiments initiated by Nissen & Bullemer (1987), however, is particularly relevant to our present concerns, in that they claim to have examined implicit learning (of a given stimulus pattern) under conditions that operationally separated the contribution of conscious awareness (of that pattern) from focal-attentive processing.

Nissen & Bullemer (1987) devised a serial reaction time task in which a light appeared at one of four locations arranged horizontally on a video monitor. Below each light location was a key, and on each trial subjects were required to press the key corresponding to the location of the light. Trials were presented in blocks of 100, consisting either of 10 repetitions of a fixed 10 trial sequence or 10 presentations of 10 randomly ordered trials.

In their initial experiment with normal subjects, eight such blocks were presented and subjects were allowed to devote their full attention to the task. Subjects given the fixed sequence had a steadily improved reaction time. After only six presentations of the sequence their group performance was significantly better than that of subjects given the randomly ordered trials and by the end of the eighth block there was a 50% reduction in their reaction time. Those given the randomly ordered trials showed little improvement. The improved reaction time, therefore, reflected the learning of the fixed sequence rather than any general characteristics of the experimental task. Subjects who learned the sequence also became aware of what they had learnt. When asked, they said they had noticed the sequence and were able to describe it by pointing to the successive locations in which the lights had appeared.

In their second experiment, Nissen & Bullemer used a divided attention task to examine the contribution of focal-attentive processing to implicit learning of the sequence. As before, normal subjects had to press a sequence of keys in response to a sequence of lights; the sequence for one group was fixed, whereas for the other group it was randomly ordered. In addition either a high or a low tone occurred at the beginning of each trial and subjects were asked to count the number of times a low tone occurred, reporting the total at the end of each block. After four such blocks, knowledge of the sequence was assessed using a "generate" task. This time, rather than responding to the appearance of a light, subjects had to press a button corresponding to where they expected the next light to appear - and accuracy rather than reaction time was the variable of interest.

Under these conditions, no significant difference in reaction time appeared between the fixed and random sequence groups, even after four blocks. The groups also performed similarly in subsequent attempts to generate the sequence - indicating that under divided attention conditions no learning of the fixed sequence had occurred.

Taken together, these experiments demonstrate the necessity of focal-attentive processing for implicit sequence learning in this particular serial reaction-time task. In themselves, however, the experiments do not dissociate focal-attentive processing from consciousness. When subjects focused their attention on successive presentations of the fixed sequence (in experiment 1) they also became more aware of the sequence (and they were able to describe it by pointing).

According to Nissen & Bullemer, a further experiment comparing normal subjects with amnesic (Korsakoff's syndrome) patients did dissociate focal-attentive processing from consciousness. In this experiment all subjects were given the serial reaction-time task and were allowed to devote their full attention to the task. On this occasion, all subjects were given four fixed sequence blocks, followed by four randomly ordered blocks. Although amnesic patients responded more slowly than normals, both groups showed a steady improvement in reaction time over blocks 1 to 4. Both groups also showed a sharp increase in reaction time as they were transferred to a random sequence in block 5 - clear evidence that the improved reaction time over blocks 1 to 4 resulted, in part, from sequence learning and not solely from increased familiarity with the task.

When questioned after block 8, all the normal subjects reported that they had noticed a repeating sequence and five (out of eight) commented spontaneously after block 5 that the pattern was no longer present. By contrast, none of the amnesic patients either reported noticing a repeating sequence or spontaneously remarked on any change.

Nissen & Bullemer conclude that sequence learning in amnesics must have involved (focal) attentive processing, because in divided attention tasks with normals, sequence learning does not take place. At the same time, sequence learning in amnesics did not appear to be manifest in awareness, because amnesics reported neither the presence of a fixed sequence nor its absence, when it changed.

It should be noted that Nissen & Bullemer's conclusion is based on the assumption that amnesics reliably report what they experience - a justifiable assumption with normal subjects that, with amnesics, cannot be taken for granted. However, implicit sequence learning (with the same task) has also been found in healthy young adults (Willingham, Bullemer & Nissen, 1989). Nor are the effects transitory. In a further study by Nissen, Willingham & Hartman (1989), amnesic patients showed normal retention of the learned sequence (without reported awareness) over an interval of one week. Sequence learning without reported awareness has also been demonstrated in normal subjects injected with scopolamine, a drug that blocks the action of acetylcholine (Nissen, Knopman & Schacter, 1987) and in normal subjects (with focal-attention, but without reported awareness) using verbal stimuli (Hartman, Knopman & Nissen, 1989). Similar effects also occur in some (but not all) patients with Alzheimer's disease (Knopman & Nissen, 1987).

Given this, it seems unlikely that learning novel stimulus patterns requires prior consciousness (of the pattern being learnt).

5. Consciousness and the control of action.

Perhaps if one is searching for some essential function of consciousness one needs to look at how action is controlled by the organism rather than at analysis, selection and storage of input, or a simple intention to respond. It is commonly thought, for example, that a reflex or well-learnt response may be performed in an unconscious, automatic fashion - whereas an adaptive response to the environment requires awareness of that environment, particularly if the required response is novel or complex.

This view is supported by the fact that interaction with the

environment is usually accompanied by awareness of the environment, of one's own action and, perhaps, of the interaction between the two. Nevertheless, there is reason to doubt that adaptive interaction requires consciousness for its operation.

5.1 Preconscious response.

Suppose a tactile stimulus is applied to the skin and one is required to press a button as soon as one feels it. It takes only a few milliseconds for the skin stimulus to reach the cortical surface. According to Libet et al. (1979), awareness of the stimulus takes longer to develop (up to around 500 msec. for a threshold stimulus). Yet, as Harth (1982) notes, one typically requires only around 100 msec. to react to such a stimulus. If so, one can signal the presence of the stimulus by pressing a button about 400 msec. before the skin stimulus enters awareness! Nonetheless, we have the subjective impression that we respond after feeling something touching the skin. According to Libet et al.(1979), this arises out of the way consciousness is "constructed" by the brain. The subjective occurrence of the skin stimulus is "referred backwards in time" to the instant it first projects onto the cortical surface - to an arrival time recorded in the brain by an early evoked potential, which acts as a "time marker" for input stimuli of this kind. Libet et al. arrived at this view by comparing how subjects experienced the relative time of occurrence of stimuli both with and without such early time markers. For example, threshold skin stimuli (which have early time markers) were judged to be roughly simultaneous with electrical stimuli applied directly to the postcentral gyrus (which have no time markers) applied 500 msec. after the tactile stimuli were applied to the skin. And, if they were applied at the same time, the skin stimuli were judged to precede the postcentral gyrus stimuli.

On the other hand, electrical stimuli applied directly to the ventroposteromedial nuclei of the thalamus do produce early time markers. The subjective timing of these stimuli accordingly resembled that of external skin stimuli. For example, they were judged to be roughly simultaneous with skin stimuli applied at the same time, but to precede postcentral gyrus stimuli applied at the same time. To be judged simultaneous with postcentral gyrus stimuli, the thalamic stimuli had to be delayed by around 500 msec. The claim that input stimuli are referred backwards in time is a radical one, and remains controversial (see BBS open peer commentary on Libet, 1985; Harnad, 1982). However, if the findings are correctly interpreted, they demonstrate a clear dissociation between cerebral information processing and awareness of that processing. In short, the conviction that consciousness enters into cerebral information processing may not be a reliable indicator that it does so.

Pressing a button in response to a tactile stimulus is of course a relatively simple task; a more complex task, such as overt identification of a stimulus, or overt discrimination between two stimuli may not be possible without awareness. This too is in doubt, however.

5.2 Overt identification and discrimination without awareness.

In some "masked priming" studies subjects seem able to make discriminative judgements about stimuli without awareness of those stimuli (see section 2.2). This also occurs in the remarkable phenomenon of "blindsight."

Weiskrantz (1986) describes an extensive series of tests carried out on a subject (D.B.) whose right visual cortex (the striate cortex) had been removed and who was consequently blind in his left hemifield. He could nevertheless make discriminative responses to stimuli presented to that field. In one study, Weiskrantz, Warrington, Sanders & Marshall (1974) required the subject to fixate a point in the centre of a screen while a random series of X's and O's was presented to the blind hemifield. As expected, the subject reported that he could see nothing. When persuaded to guess, however, he made a correct identification on 27 out of 30 trials; in another series of tests with vertical and horizontal stripes, the subject guessed correctly on all 30 occasions.

In other studies Marcel (1982) reports that although cortically blind subjects have no phenomenal experience of an object in their blind hemifield they can preadjust their hands appropriately to the size, shape, orientation, and 3-D location of that object when forced to try to grasp it (see also Perenin & Jeannerod, 1978; Torjussen, 1978; Stoerig, Hubner & Poppel, 1985). It is interesting that a similar phenomenon, "blind-touch," has been reported in the somatosensory domain. Paillard, Michel & Stelmach (1983) describe a patient with hemi-anaesthesia caused by a cortical lesion in the sensorimotor cortex who could locate touch stimuli applied to her hand, but had no awareness of being touched.

Campion, Latto & Smith (1983) have argued that blindsight findings may be artifactual; it may be, for example, that the striate is not completely damaged in patients exhibiting some residual visual functioning. Weizkranz (1988) agrees that prior to post-mortem, one cannot rule this out. However, he points out that this possibility is far-fetched in blindsight cases where complete unilateral hemispheric decortication obtains (Perenin & Jeannerod, 1978).

Campion et al also suggest that residual vision might have arisen from stray light originating from the stimulus and diffused onto intact regions of the visual field, to produce a subtle form of stimulation of which the subjects remained unaware. Weiskrantz (1983,1986,1988) reviews various sources of evidence against this. For example, one naturally occurring control for stray light was provided by the optic disk of subject D.B., which fell within his blind hemifield. Within the optic disc, nerve fibres penetrate the retina and no receptors exist. In this region, therefore, the eye is truly blind. Accordingly, when a spot of light (suitably adjusted for intensity and contrast) was projected onto D.B.'s optic disc, he could not see it and his ability to guess whether or not it was present remained at chance. Hence, the spot could not have been a source of stray light; when it was directed to the blind hemifield just adjacent to his optic disc D.B. still maintained he could not see it, but his ability to guess whether or not it was present was very good. This provided clear evidence that "blindsight" is not an artifact.12

Hence, under exceptional circumstances, it seems possible not only to analyze a visual stimulus but also to make an appropriate, overt identification response to it, without any accompanying visual awareness.

5.3 Unconscious control of complex, novel, motor adjustments.

The above findings deal with identification responses to stimuli that do not enter awareness. Responses of this kind, however, require little monitoring or feedback of the kind needed to adapt the movement of muscles and limbs to novel, complex or changing situations. According to some theorists (e.g. Underwood, 1982), this is what consciousness provides.

It is clear that not all forms of feedback in the central nervous system require consciousness for their operation. Homeostatic mechanisms controlling body temperature, blood sugar levels and so forth operate in an entirely unconscious fashion, as do the various forms of proprioceptive feedback that signal the positions of limbs and muscles. Consciousness seems to arise whenever we are called upon to make some novel adjustment to an external situation (a point noted by Romanes, 1895). In such situations, according to Mandler (1975), consciousness may perform a "troubleshooting" function. One might, for example, be driving a car in more or less automatic fashion, but if the brakes suddenly fail, consciousness is immediately directed towards "getting repair work under way."

Yet, even in these situations the question of what consciousness

contributes to adaptive interaction remains. Dixon (1981) notes that there are cases where emergency adjustments need to be made too quickly for (relatively slow) conscious processing to operate, for example, when a driver needs to make an immediate response to avoid the sudden threat of an accident. The manipulation of steering wheel, accelerator and brake may take place with a very high level of competence and accuracy. Yet, after the event, the driver may exclaim (quite truthfully) "I don't know how I missed him." In this situation, complex muscular adjustments to a novel, rapidly changing situation appear to take place prior to the advent of consciousness. Anecdotal accounts of the need for consciousness in situations where complex or novel motor adjustments are required are therefore inconclusive. Whereas emergency situations demand one's full focal attention and whereas focal attention is usually accompanied by consciousness, it does not follow that consciousness is necessary for complex motor adjustments to be made. Indeed, one might ask, even if consciousness has time to emerge and one is conscious of the task demanding one's attention, just how "conscious" is "conscious control"?

One has no awareness whatsoever of the myriad motor commands issuing from the central nervous system that travel down efferent fibres and innervate the muscles, nor of the complex motor programming that allow muscular co-ordination and control. In speech, for example, the tongue may make as many as 12 adjustments of shape per second - adjustments which need to be precisely co-ordinated with other rapid, dynamic changes within the articulatory system. According to Lenneberg (1967), "Within one minute of discourse as many as 10 to 15 thousand neuromuscular events occur." Yet only the results of this activity (the overt speech) normally enters consciousness.

5.4 Unconscious planning.

Unconscious motor control might of course be the result of prior conscious activity. For example, Popper (1972) and Mandler (1975) suggest that consciousness is necessary for short and long-term planning, particularly where one needs to create some novel plan or novel output response. In the case of speech production, for example, the control of the articulatory system might be unconscious but planning what to say might be conscious, particularly if one is expressing some new idea, or expressing some old idea in a novel way.

The planning and execution of speech has been subject to considerable experimental examination. Speech production seems to involve various complex levels of organization. According to Bock (1982), these can be roughly divided into six, relatively distinct "arenas": a referential arena in which some nonlinguistic coding of thought is transformed into a format that can be used by the linguistic system, a semantic arena in which the propositional relations formed within the referential arena are meshed with lexical concepts, a syntactic arena responsible for structuring lexical items into conventional surface grammatical forms, a phonological arena in which lexical items are mapped onto phonological representations, a phonetic arena that translates phonological codes into codes suitable for entry into motor programmes (e.g. target vocal-tract configurations), and a motor assembly arena responsible for the actual compiling and running of the motor programmes.

These levels of organization are commonly thought to be hierarchically arranged, with communicative intentions being translated into a syntactic form with a given lexical content, in a largely top-down fashion (Dell, 1986; Foss & Hakes, 1978; Garrett, 1982; Liberman, Cooper, Shankweiler & Studdert-Kennedy, 1967; Schaffer, 1984).13 As noted above, articulatory control (motor programming and execution) is largely unconscious. According to Bock, syntactic planning by skilled speakers is also relatively automatic and outside conscious voluntary control. Planning what to say and translating nonverbal conceptual content into linguistic forms, however, requires effort.14 Could it be that such planning is conscious? Let us see.

A number of theorists have argued that periods of conceptual, semantic and syntactic planning are characterised by gaps in the otherwise relatively continuous stream of speech (Goldman-Eisler, 1968; Boomer, 1970). The neurologist John Hughlings Jackson, for example, suggested that the amount of planning required depends on whether the speech is "new" speech or "old" speech. Old speech (well known phrases, etc.) requires little planning and is relatively continuous. New speech (saying things in a new way) requires planning and is characterised by hesitation pauses. Fodor, Bever & Garrett (1974) point out that breathing pauses also occur (gaps in the speech stream caused by the intake of breath) - and breathing pauses do not, in general, coincide with hesitation pauses.

Breathing pauses nearly always occur at the beginnings and ends of major linguistic constituents (such as clauses and sentences); they therefore appear to be co-ordinated with the syntactic organization of such constituents into a clausal or sentential structure. Hesitation pauses tend to occur within clauses and sentences and appear to be associated with the formulation of ideas, deciding which words best express one's meaning, and so on.

Accordingly, in assessing whether the planning of what to say is conscious, it is instructive to examine what one experiences during a hesitation pause (where we have good reason to infer such planning to be taking place). This simple thought experiment reveals that during a hesitation pause one might experience a certain sense of effort (perhaps the effort to put something in an appropriate way), but nothing is revealed of the processes which formulate ideas, translate these into a form suitable for expression in language, search for and retrieve words from memory, assess which words are most appropriate, and so on. In short, no more is revealed of conceptual or semantic planning in hesitation pauses than is revealed of syntactic planning in breathing pauses. The fact that a process demands effort does not ensure that it is conscious. Indeed, there is a sense in which one is only aware of what one wants to say after one has said it!

Nor is the situation any different if one expresses one's thoughts in covert speech through the use of phonemic imagery. Covert speech and overt speech bear a similar relation to the planning processes that produce them. In neither case are the complex antecedent processes available to introspection. Furthermore, overt and covert speech are, in principle, "productive," in that one can produce an indefinitely large number of sentences, including sentences which have never been produced before. Consequently, the unconscious planning of speech must involve, at least to some extent, the planning of novel responses.

It could be argued, however, that merely saying something in a new way does not require genuine creativity. After all, how often does one express a genuinely new idea? Perhaps it is in the creation of a novel idea that consciousness plays some essential role.

6. Consciousness and creativity.

Studies of creativity in both artists and scientists indicate that creative thought usually requires a preparation period, an incubation period, and a consolidation period (Patrick, 1955; Ghiselin, 1952; Thomson, 1966; Platt & Baker, 1969; Bowers, 1984).

As Thomson (1966) points out, "No intuitions come without hard work." Preparation in creative writing might require an initial idea to be reworked or rewritten. In science, a period of data collection and analysis may be followed by an initial formulation of a theory, or an initial attempt to deal with unresolved problems. Such efforts require one's focal attention and are duly accompanied by consciousness (of what is being read, written, reworked, and so on).

It should be clear from the discussions of overt and covert speech above that one can become conscious of one's thoughts (on a given issue) without consciousness having entering into the formulation of such thoughts. Moreover, if a creative "leap of imagination" is necessary, this initial processing may not lead to success; an additional incubation period may be required. This period is characterised by the absence of conscious effort. One might simply turn one's attention elsewhere or, indeed, "sleep on the problem."

After such an incubation period a creative solution may suddenly emerge into consciousness, without warning and, apparently, without effort. As the poet Stephen Spender observes, "Everything is work except inspiration" (see Ghiselin, 1952). There are, for example, a number of well-documented cases of intuitive insight emerging in dreams. Famous examples include Henri Poincare's proof that there are no mathematical functions such as Fuchsian functions (Thomson, 1966), Otto Loewi's discovery of how to do a fundamental experiment on the chemical transmission from the vagus nerve to the frog's heart (Popper & Eccles, 1976) and Auguste Kekule's discovery that benzene forms a closed hexagonal ring (Hein, 1966 - but see Browne, 1988).

There are many more examples of such intuitive insights in

science (Platt and Baker, 1969). In general, such insights need to be followed by a further consolidation period. Like the preparation period, this engages focal attention with its accompanying conscious contents. Yet the heart of the creative act (the conceptual reorganization required to make the intuitive leap) is associated with the incubation period, in which processes not accompanied by consciousness dominate (see Thomson, 1966 and Bowers, 1984 for a discussion). Creativity, therefore, cannot be one of the special functions of consciousness.

7. Does consciousness enter into subsequent information processing?

In the tasks discussed above, when consciousness appears, it follows the information processing to which it relates and does not enter into it. It remains possible, however, that what enters consciousness has an effect on subsequent information processing. From a first-person perspective, there seems to be little doubt that prior conscious states influence subsequent conscious states; for example, one thought may lead to another, or to a feeling, or to an action, and so forth.

From a third-person perspective, however, things look very different. As noted earlier, consciousness normally accompanies focal-attentive processing. Conversely, when consciousness is absent, focal-attentive processing is usually absent. This simple point explains why processing which is accompanied by consciousness may have effects (on subsequent tasks) very different to nonconscious processing (for example, in the studies of priming and masked priming discussed above). It also explains why some tasks appear to require consciousness for their successful completion (they require focal-attentive processing).

In the analysis of input, for example, focal-attentive processing not only enables an item to enter consciousness, but also to update long-term memory in a way that allows potential recognition or recall. Information not given focal-attentive processing, on the other hand, is either inaccessible or lost from the system. Focal-attentive processing also activates traces related to the input and inhibits traces not related to the input, whereas non focal-attentive processing simply produces activation of related traces (see sections 1.3 and 2.2).

But this does not establish that the conscious states which accompany focal-attentive processing themselves enter into subsequent information processing. According to Mandler (1985), however, they do so. Mandler suggests that while information must be at a certain level of activation in order to become conscious, once it does so it will receive additional activation, which is mediated by consciousness, resulting in further enhancement. Such information is then more likely to be utilized in subsequent thoughts and actions, a desirable consequence, given that it relates most closely to current concerns. As he notes,

"The proposal can easily be expanded to account for some of the phenomena of human problem solving. I assume that activation is necessary but not sufficient for conscious construction and that activation depends in part on prior conscious constructions. The search for problem solutions and the search for memorial targets (as in recall) typically have a conscious counterpart, frequently expressed in introspective protocols. What appear in consciousness in these tasks are exactly those points in the course of the search when steps toward the solution have been taken and a choice point has been reached at which the immediate next steps are not obvious. At that point the current state of world is reflected in consciousness. That state reflects the progress toward the goal as well as some of the possible steps that could be taken next. A conscious state is constructed that corresponds to those aspects of the current search that do (partially and often inadequately) respond to the goal of the search. Consciousness at these points truly depicts waystations toward solutions and serves to restrict and focus subsequent pathways by selectively activating those that are currently within the conscious construction." (p77 - italics added)

The sense in which the present analysis differs, on this point, from that of Mandler can be gleaned from the final sentence of the quotation. As noted earlier, items enter consciousness only if they are (or have recently been) subject to focal-attentive processing. Accordingly, what enters consciousness during problem solving "truly depicts waystations toward solutions" for the reason that such conscious contents reflect the state of progress of focal-attentive processing. If "two-process" theory is correct, focal-attentive processing also activates (or inhibits) subsequent representational states.

Given this, it is not clear what additional activation mediated by consciousness would achieve. Only information selected for focal-attentive processing enters consciousness. According to "activation" theories of attention, this will only occur if it is already more activated than competing, less relevant information - in which case no additional, "consciousness-mediated activation" would be required to ensure its prominence in subsequent activity.

8. How consciousness relates to focal-attentive processing.

It is important to remember in this regard that in its ordinary usage "consciousness" refers to something other than "focal-attentive processing." It refers primarily to "awareness," whereas "focal-attentive processing" refers to a functional subdivision within an information processing model of the brain. Focal-attentive processing is thought to be a necessary condition for conscious awareness. Operationally, however, they are distinct (Nissen & Bullemer, 1987; Kahneman & Treisman, 1984).

Conscious contents are typically investigated by the use of subjective reports (of subjective experience) - usually verbal reports, although various other means of communicating experience exist (Ericsson & Simon, 1984; Pope & Singer, 1978). By contrast, human information processing and functional divisions within such processing are typically inferred from performance measures such as reaction time, error score, and so forth.

In principle, therefore, it might be possible to obtain evidence of focal-attentive processing in the absence of awareness (of what is being processed). In practice, however, a complete dissociation of consciousness from focal-attentive processing is difficult to achieve, as the disruption of consciousness is also likely to interfere with at least some aspects of (normal) focal-attentive processing.

For example, blindsighted subjects direct their attention to an input stimulus, identify its properties and make appropriate identification responses, but are unable to experience the stimulus to which they attend (Weiskrantz, 1986). Such subjects, however, need to be forced to make decisions about stimuli they believe they cannot see, indicating that information about the stimulus is not readily available to all parts of the information processing system. Similarly, Marcel (1986) found that blindsight patients make no attempt to grasp a glass of water in their blind field even when thirsty, suggesting that information about the input remains dissociated from systems subserving voluntary control.

In "masked priming" experiments, the mask may interfere not only with consciousness of the prime but also with the usual inhibition of traces which do not relate to the prime (Marcel, 1980) and with other consequences of focal-attentive processing (Marcel, 1983 experiment 5; Forster & Davis, 1984; Cheesman & Merikle, 1984,1986; Dagenbach, et al, 1989).

In hypnotic analgesia, the "hidden observer" claims to remember pain, which the hypnotised patient, in surgery, says he does not experience - suggesting that focal-attentive processes required to update long-term memory are partially dissociated from those subserving conscious experience. The absence of experienced pain, however, may be accompanied by an absence of physiological indices of pain and by reduced bleeding and salivation (Oakley & Eames, 1985), indicating that information about the painful input may not be readily available to other parts of the system (as with the cases of blindsight and visual masking discussed above). Similarly, in implicit learning and memory studies, information which is not present to consciousness at the time of learning (according to subjective reports) may update long-term memory but may not be available for later explicit recognition and recall (Reber, 1989; Nissen & Bullemer, 1987).

Even partial dissociations provide useful information, however, in that they enable one to be more precise about what aspect of focal-attentive processing might relate most closely to consciousness. The above findings, for example, suggest that the processing required for information to enter consciousness may also be required to make that information generally available to other parts of the system. As Kahneman & Treisman (1984) suggest, the dissemination of currently processed information to other information processing modules may be one of the functions of focal-attentive processing.

This view is also similar to one that has recently been developed, in depth, by Baars (1989). According to Baars, the principle function of consciousness is to enable information to be "broadcast" throughout the central nervous system. If the above arguments are correct, however, this is not the function of consciousness. Rather, the processes which enable information to be integrated into a particular conscious state also enable that information to be broadcast to other parts of the system. Consciousness results from such focal-attentive processing but does not enter into it.

9. General discussion.

9.1 Is human information processing conscious?

In the above examples, we have ranged over all the main phases of human information processing - from information encoding, storage, retrieval, and transformation to output. We have considered the role of consciousness in the analysis and selection of stimuli, in learning and memory, and in the production of voluntary responses, including those requiring planning and creativity.

In one sense, each of these tasks may be "conscious" (if it is at the focus of attention). We may be conscious of the stimuli that we analyze and select for more detailed attention, conscious of what we learn and commit to memory, and conscious of the responses we make to such stimuli. When the required responses are complex or novel we may be aware of devoting effort to planning and monitoring their execution. In reflective thought or problem solving we may have some awareness of internal processing in the form of thoughts, emotions, images, and so forth. Whether consciousness is necessary for such processing, however, is a different matter.

Some processes operate either with or without accompanying awareness, including aspects of input analysis, memory and overt response. Consequently, these cannot require awareness for their operation. More important, there is a sense in which the execution of none of these tasks is "conscious" (even if they are at the focus of attention, and are accompanied by awareness).

The detailed information processing required to analyze and select amongst stimuli, or to encode them in memory is not, by and large, available to introspection, nor is there any awareness of the processing required to execute a response. Rather, one becomes aware of a stimulus only after one has analyzed and selected it, and aware of one's own response only after one has executed it. This applies not only to simple, automatic responses (such as pressing a button or detecting a stimulus) but also to complex, novel, voluntary responses (such as the production of "new" speech).

In similar fashion, awareness of "inner responses" follows the processing required to produce them. For example, covert speech results from the antecedent processing involved in thinking, problem solving, remembering, silent reading, and so forth. This applies equally to the "intuitive insights" which are the product of the creative process.

As noted earlier, conscious contents that follow given forms of information processing cannot be thought of as entering into that processing. Nor does consciousness as such enter into subsequent information processing. Rather, it is the focal-attentive processing which provides (at least some of) the necessary conditions for conscious awareness that also influences the course of subsequent processing operations.

If consciousness does not enter into human information processing, then the very notion that some of this processing is "conscious" needs re-examination. In retrospect, a process might be said to be "conscious" in three distinct senses. It might be "conscious"

(a) in the sense that one is conscious of the process

(b) in the sense that the operation of the process is accompanied by consciousness (of its results)

and (c) in the sense that consciousness enters into or causally influences the process.

Some processes (problem solving, thinking, planning, and so on) are conscious in sense (a) but only in so far as their detailed operation is accessible to introspection. Many processes (input analysis, motor control, thinking, planning, etc.) are conscious in sense (b), in so far as they engage focal-attentive processing. However, no human information processing is conscious in sense (c).

The theoretical implications of this are far-reaching. If consciousness does not enter into human information processing then processes which allow adaptive functioning in the human brain must be distinguished from accompanying awareness. If so, information processing models (and other models) that deal solely with how input is transformed into behavioural output remain seriously incomplete, for they do not contain consciousness within their workings.15

9.2 Some implications for the philosophy of mind.

The above conclusions also have consequences for the philosophy of mind. These cannot be fully dealt with in the space available for this target article. A brief outline, however, may provide a useful basis for discussion.

It should be apparent that the dissociation of awareness from cerebral functioning poses problems for reductionist theories of consciousness. It is inconsistent with the functionalist view that consciousness simply is (ontologically identical to) a mode of functioning of the brain.16 Nor is it consistent with physicalism (the view that consciousness is ontologically identical to a physical state of the brain)17 - unless one is willing to accept that some cerebral states exist that neither have a function in themselves nor influence the development of subsequent, functional, cerebral states or processes. The exclusion of consciousness from cerebral functioning is equally inconsistent with emergent interactionism (the view that consciousness emerges from cerebral activity but then supervenes over the activity from which it emerges - see Sperry, 1985) and with interactionist forms of dualism (the view that a disembodied consciousness engages in reciprocal interaction with the brain - see, e.g. Popper & Eccles, 1976; Eccles, 1980, 1987).

But what alternatives remain? According to the behaviourists, one should simply exclude consciousness from psychological science, and recently, some philosophers have questioned whether consciousness is a genuine phenomenon (Dennett, 1988; Rey, 1988). Unfortunately for such views, consciousness has been subject to extensive scientific investigation.

From an experimenter's perspective, the contents of a subject's consciousness may not be directly observable, but they may nevertheless be inferred to be a form of output accompanying certain forms of information processing. Accordingly, the physical, psychological and neurophysiological determinants of these contents have been extensively explored in perception, psychophysics, sensory physiology and many other domains of the psychological and brain sciences, along with the processes which enable those contents to be formed into an integrated whole (see Blumenthal, 1977, for a review). In recent years, moreover, there has been a renewed interest in structured subjective reports and other methods of phenomenological enquiry (Ericsson & Simon, 1984; Pope & Singer, 1978). There has also been extensive investigation of how processes that are accompanied by consciousness differ from processes that are not, revealing major functional subdivisions in human information processing. Ultimately, such studies may enable one to specify, in information processing terms, what the necessary and sufficient conditions for consciousness may be - conditions which are linked, in the present analysis, to certain aspects of focal-attentive processing. In principle, these conditions can also be specified in neurophysiological terms (see Eccles, 1980,1987; John, 1976; Pribram, 1971,1982; Dimond, 1980; Uttal, 1978; O'Keefe, 1985; for some initial speculations). If consciousness is not a genuine phenomenon, then what is the subject matter of these enquiries?

9.3 Complementary first-person and third-person perspectives.

Even if one accepts that consciousness is central to an understanding of the mind (Searle, 1990; Velmans, 1990a,1990b) its causal status remains a puzzle. According to the above, consciousness is a form of output (associated with focal-attentive processing) that does not enter into cerebral processing. This appears to support epiphenomenalism (the view that brain events have causal effects both on other brain events and conscious experiences, but conscious experiences have no causal effects on the brain - see Huxley, 1898).

It must be emphasised, however, that the above analysis reviews the evidence only as it appears from a third-person, external observer's perspective. While from a third-person perspective consciousness appears to have no causal influence on human brain activity and overt behaviour, from a first-person perspective, things look very different.

From a first-person perspective consciousness appears to exert a central influence on human affairs, and scientists have a first-person perspective as much as their subjects. It is not surprising, therefore, that consciousness has been thought to enter into every major phase of information processing, ranging from the analysis, selection and storage of input to the organization, planning and execution of response. Experiences also appear central to human motivation - ranging from the wish to engage in pleasant experiences and to avoid painful ones, to engaging in activity simply to extend the breadth and depth of one's experience. Experiences of the world are also thought to influence human development. Traumatic experiences, for example, may have unwanted psychosomatic effects. Such examples of apparent causal efficacy are innumerable. From a first person perspective, therefore, epiphenomenalism appears false.

Traditionally, science has adopted the third-person, external observer's perspective, and, as the review above demonstrates, it is possible, in principle, to translate first-person accounts of mental activity into third-person accounts (for example, into information processing models which make no appeal to consciousness entering into cerebral activity). But the fact that first-person accounts can be translated into third-person accounts does not alter the fact that subjects have a first-person perspective from which to view the world, including their own activity (Harnad, 1991; Nagel, 1974,1986).

Moreover, the fact that a third-person account is possible in principle does not guarantee that it is preferable. While brain functioning may need to be understood from the perspective of an external observer, for most everyday purposes a first-person account of the determinants of action (in terms of what is perceived, thought, felt, believed, desired, and so forth) may be more informative. In short, while explanations in terms of brain states, information processing, and the like are preferable for some purposes, explanations in terms of what is perceived, felt, and so forth are more useful for others.

Of course, the question of whether it is actually a given brain state or a given experience that determines a particular behaviour remains - and, on this point, I suggest, no choice is necessary. These are events viewed from different perspectives. Events viewed from an external observer's perspective (via exteroceptors) appear different from the same events experienced by the subject (via interoceptors) because the methods of observation are different. However, each perspective is legitimate.

Information processing models and other third-person perspective models are incomplete in so far as they do not encompass the subject's first-person perspective. Conversely, a subject's first person account of his actions (based on what he experiences) is incomplete in so far as it does not encompass information available to an external observer. In this sense, first-person and third person perspectives are complementary and mutually irreducible. A complete psychology requires both (Velmans, 1990b).

How first-person and third-person accounts relate requires detailed examination (and this cannot be done in the space available). Once one accepts this psychological "complementarity" principle18, however, it is clear why consciousness does not enter into human information processing - for information processing models systematize what can be observed only from a third-person, external observer's perspective. The objection to theories that attempt to insert consciousness into such (third-person) models is not that consciousness is causally ineffective. Viewed from a first-person perspective, consciousness is central to the determination of human action. Rather, information processing models that attempt to incorporate consciousness within their workings collapse the subject's first-person perspective into the external observer's third-person perspective, a collapse of one perspective into the other which a "complementarity" principle would not allow.

10. Summary

1. Human information processing may be "conscious" in so far as some of its aspects are available to introspection. It may also be accompanied by consciousness of its results.

2. Introspective access, or consciousness of the results of cerebral processing must not be confused with

the operation of that processing. What enters awareness follows the processing to which that awareness relates and cannot therefore enter into it. This applies to all stages of information processing, whether the information is simple or complex, familiar or novel, whether the processing is involuntary or voluntary, and whether the processing is data-driven, cognitively driven or a combination of the two.

3. Processes that are accompanied by consciousness are at the focus of attention. It appears that consciousness is closely linked to that aspect of focal-attentive processing which makes information generally available throughout the processing system.

4. Processes at the focus of attention function differently from those which are not. For example, focal-attentive analysis of input appears to activate relevant information and to inhibit irrelevant information; stimuli given focal-attentive processing appear to be potentially available for subsequent recognition and recall; information given focal-attentive processing may also be generally available to other parts of the system.

Consequently, focal-attentive processing may be required in various situations - for the identification of novel stimuli, for learning and memory, for the control of complex, novel responses involving planning and creativity, and so on.

5. When consciousness is absent, focal-attentive processing is usually absent - which explains why consciousness seems necessary for the completion of such tasks.

6. If consciousness does not enter into cerebral functioning then human information processing models which restrict themselves to an account of that functioning remain seriously incomplete, in so far as they do not contain consciousness within their workings.

7. Consciousness is, nevertheless, amenable to scientific investigation. Accounts of functioning therefore need to be supplemented by accounts of sentience within the human brain. A complete psychology requires both.

8. The dissociation of consciousness from cerebral functioning also poses problems for philosophy of mind. Consciousness neither interacts with the brain, nor can it be reduced to a state or function of the brain.

9. At the same time, the existence of consciousness - of a "first-person" perspective, cannot be dismissed. Nor can one dismiss the everyday usefulness of "first-person" psychological accounts.

10. Information processing models view the brain from an external observer's "third-person" perspective, which cannot encompass the subject's "first-person" perspective. These two perspectives appear to be complementary, and mutually irreducible.

FOOTNOTES

1.See Baars (1989), Carr & Bacharach (1976), Dixon (1971,1981), Holender (1986), Kihlstrom (1987), and Mandler (1975, 1986) for reviews.

2.For example, consciousness is thought to be necessary for the analysis of novel stimuli or novel stimulus arrangements (Posner & Snyder, 1975; Bjork, 1975). According to Mandler (1975,1985), consciousness allows us to choose amongst competing input stimuli. Other theorists have assumed that conscious processing is necessary for a stimulus to be remembered (James, 1890; Underwood, 1979; Waugh and Norman, 1965) and for the production of anything other than an automatic, well-learnt response, e.g. for a voluntary response that is flexible or novel, or for a response that requires monitoring (feedback) or planning (Romanes, 1895; Mandler, 1975,1985; Shiffrin & Schneider, 1977; Underwood, 1982).

According to some theorists consciousness enables us to interact with our environment in a "reflective" rather than an automatic fashion (Mandler, 1975,1985; Dixon, 1981). There are many further views (see recent discussions in Baars, 1989; Blakemore & Greenfield, 1987; Marcel & Bisiach, 1988). Baars (1989), for example, suggests no less than eighteen different functions for consciousness in human information processing!

3.Messages which are not at the focus of attention in shadowing tasks are referred to as "nonselected messages" (in the nonselected ear) rather than "nonattended messages", because they may be subjected to sophisticated analysis and may, in this sense, may be receiving attention (see section 2.1).

4.Posner & Snyder (1975) for example, claim that all inputs receive an initial, automatic, parallel analysis for meaning that is essentially free of processing capacity limitations.

5.One method of operationalizing this distinction is suggested by Nissen & Bullemer (1987), discussed in section 4.4.

6.This assumes that subjective reports provide a valid basis for assessing whether or not an item enters consciousness, an issue to which we return in section 2.2.

7.It should be noted that this interpretation of the findings is quite different from that given by Holender (1986). According to Holender, the disambiguation which occurred in Lackner & Garrett's study was so complex that it would have been impossible without "focal-attentive switching" to the nonselected ear, in which case the analysis of nonselected sentences must have been conscious. This question cannot be settled by fiat, however. If subjects had consciously analyzed the meanings of the sentences in the nonselected ear and had consciously integrated their meanings with those of the relevant, ambiguous sentences, it is difficult to understand why they could give no systematic information about nonselected sentences when asked. Such ignorance would not obtain, after all, for a context sentence presented at similar intensity, but to the attended ear, prior to the target, ambiguous sentence. Holender concedes, furthermore, that focal-attentive switching in Treisman's studies was unlikely. Her findings therefore also suggest that complex messages can be analyzed outside the focus of attention. If such messages are pertinent, they may subsequently attract focal attention and intrude into consciousness, which is why bilingual subjects (in Treisman, 1964b) often found it difficult to prevent giving a shadowing response in mixed English and French.

8.See Holender & BBS open peer commentary, 1986; and Dagenbach, Carr & Wilhelmsen, 1989, for a summary.

9.Entry of the stimulus into consciousness (being aware of the stimulus) might accompany, or be a product of focal-attentive processing without exerting a causal influence on focal-attentive processing. Hence, I do not take it for granted that the effects of focal-attentive processing and entry into consciousness are one and the same (see section 7).

10.See also Carr, Davidson & Hawkins, 1978; Brown, Carr & Chaderjian, 1987, for evidence that visual analysis of verbal input stimuli may be, to some extent, under strategic control.

11.See Carr & Bacharach, 1976; Dixon, 1981, p.259, for an initial review of some of the factors involved.

12.A similar control and result has also been reported by Stoerig et al. (1985).

13.Bock (1982) reviews evidence that factors affecting lexical retrievability (e.g. semantic and phonological priming) are also associated with certain syntactic modifications in sentences, suggesting that the production system might be subject to bottom-up as well as top-down influences.

14.According to Bock (1982), processing in the referential domain draws heavily on working memory capacity.

15.This applies equally to recent alternatives to information processing models, such as parallel distributed processing.

16.Philosophical functionalists such as Dennett (1978) argue that consciousness has functional aspects which are ontologically identical to the contents of a hypothetical memory buffer "M." In similar fashion, cognitive psychologists have assumed the contents of consciousness to be identical to the contents of "primary memory" or some similar short-term store (James, 1890; Waugh and Norman, 1965); Posner and Warren (1972) define a "conscious process" to be one that makes use of the "limited capacity central processor"; others view "conscious processing" and "focal-attentive processing" to be one and the same (Miller, 1987; Mandler, 1975), and so forth.

17.A recent, sophisticated defence of physicalism is given by Searle (1987).

18.It is to tempting to relate "psychological complementarity" to complementarity in physics. One must treat such analogies with caution, however, as there are both similarities and differences. According to quantum mechanics, wave and particle descriptions of light are complementary and mutually irreducible.

For completeness, both descriptions are required. Its appearance as waves on some occasions and particles on others depends entirely on the conditions of observation (which makes the conditions of observation integral to what is observed). In this sense, physical complementarity and psychological complementarity appear similar. Wave and particle descriptions, however, both derive from the third-person perspective, and the relation of first-person to third-person accounts in psychology is far more complex (e.g. see Ericsson & Simon, 1984, for an initial attempt to relate first-person introspective reports to a third-person information processing model of the brain).

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