KELLY ROE (AUDITING): ASSIGNMENT FOUR

In the case of such longer-latency reentrant attention effects in low-level sensory areas, do you think that this should be considered early selection, late selection, or something else? What would we need to know about the function of this late modulation to answer this question? What kinds of experiments could be done in the future to better understand this issue?

One dimension on which we can distinguish 'early selection' and 'late selection' is in terms of the amount of time (latency) between the onset of the stimulus and and the effects of attention. I shall call this the (T) dimension (for 'time'). There could be different notions of (T)early as follows: (T)early$_{70}$ which refers to latency of less than 70ms, (T)early$_{100}$ which refers to latency of less than 100ms, (T)early...t which refers to latency of less than ...$t$ms. We could go through a similar process to define different notions of (T)late. While theorists can agree as to whether one process is (T)earlier than another process it is important to note that theorists could disagree as to whether a finding indicates 'early' or 'late' effects of attention depending on what latencies they accept as 'early' or 'late'. If one theorist defines (T)late as a process that occurs after 100ms while another theorist defines (T)late as a process that occurs after 70ms then they are going to (seem to) disagree as to whether an effect at 80ms is late or not, for instance.

Another dimension on which we can distinguish 'early selection' and 'late selection' is in terms of how peripheral or central an anatomical structure is. I shall call this the (A) dimension (for 'anatomical'). There could be different notions of (A)early as follows: (A)early$_{thalmus}$, (A)early$_{V1}$, (A)early$_{V2}$, (A)early...a. We could go through a similar process to define different notions of (A)late. Just as with different (T) notions, different (A) notions could result in agreement that there are effects of attention at location a and agreement over whether one process is (A)earlier than another— but there could still be disagreement over whether this provides evidence for 'early' or 'late' selection depending on the particular notion of (A)early that one adopts. Finding evidence that attention affects V2 will only count as evidence for (A)early effects of attention if a theorist regards V2 to be A(early), for example.

Re-entrant processes are interesting because they show that the (T) dimension and the (A) dimension (as defined above) can come apart. We can agree that 300ms after onset of stimulus is (T)later than 100ms after onset of stimulus. Re-entrant processes thus are unambiguously (T)later than other effects of attention. Whether re-entrant processes are (T)early (simplicitor) will depend on which notion of (T)early one adopts, however (as illustrated in the first paragraph). We can similarly agree that V2 processing is (A)earlier than association area processing. Re-entrant processes thus are unambiguously (A)earlier than other effects of attention. Whether re-entrant processes are (A)early (simplicitor) will depend on which notion of (A)early one adopts, however (as illustrated in the second paragraph). At this point the issue seems to be whether 'earlier' should track the reference of the (T) or the (A) notion when they come apart (as they are found to do in the case of re-entrant processing).

At this point we may well start to wonder what the fuss is all about[1]. The dispute is starting to sound purely verbal and like this whole issue could be avoided if people simply described their finding (as in the third paragraph) rather than worrying about whether the finding should be called 'early' or 'late'. In order to see the significance of the problem it will be useful to consider firstly how cognitive neuroscientists got to be interested in the issue of 'early' vs 'late' effects of attention, secondly how the finding problematizes feedforward assumptions, and thirdly how the finding raises issues that have yet to be resolved.

The dispute seems to have originated in cognitive psychological theories of 'early selection' and 'late selection'. 'Early selection' theorists maintained that attention could affect early processing by which they seemed to mean the processing of stimulus features such as whether a speaker is male vs female, young vs old, speaking english vs chinese, etc. In contrast, 'late selection' theorists maintained that attention affected processing of 'higher level' stimulus features such as processing for semantic meaning and / or encoding and / or retrieving from memory. The assumption seems to be that basic sensory features must be processed before more complex sensory features that then feed into motor systems (so a (T) / (F) feedforward assumption, in effect). This processing is (plausibly enough) expected to take time and hence

[1]Well, philosophers might be tempted to at any rate.

the interest in the temporal dimension as a relevant measure of the sensory and non-sensory functional distinction).

There is a schematic diagram in the textbook of how cognitive psychologists (roughly) envisaged this distinction mapping onto the brain. Subcortical areas were regarded to be 'early sensory' and temporally early whereas cortical areas (including V1-V4) were considered 'late non-sensory' and temporally late. This schematic differs from the way in which cognitive neuroscientists have come to distinguish (A)early from (A)late processing regions, however. In particular, the cortical regions V1-V4 are considered '(A)early sensory' processing areas by cognitive neuroscientists. The rationale for considering VI-V4 to be 'early' processing areas seems to be that those anatomical areas function to process the sorts of stimulus features that cognitive psychologists considered 'early', however. Our interest in anatomical dimension of 'early' and 'late' seems to be motivated by the assumption that information processing must follow anatomical pathways in the brain and that sensory processing areas feed into association processing areas which feed into motor production areas (so a (F) / (A) feedforward assumption, in effect).

It thus seems that another dimension on which we can distinguish 'early selection' and 'late selection' is in terms of how functionally low vs. high level the features are that are being processed. I shall call this the (F) dimension (for 'functional'). There could thus be different notions of (F)early as follows: (F)early$_{voice-vs-noise}$, (F)early$_{male-vs-female}$, (F)early$_{english-vs-chinese}$, (F)early...*f*. We could go through a similar process to define different notions of (F) late. Just as with different (T) and different (A) notions, different (F) notions could result in agreement that there are differences in the information that is being processed and agreement over whether one process is (F)earlier than another— but there could still be disagreement over whether this provides evidence for 'early' or 'late' selection depending on the particular notion of (F)early that one adopts. Finding evidence that attention affects the processing of sensory feature x will only count as evidence for (F)early effects of attention if a theorist regards sensory feature x to be F(early), for example.

We have considered already how re-entrant processing shows us that the temporal and anatomical dimensions are distinct. If we accept that the functional dimension is more important than either of these (as I think we should if we are interested in the prospects for an integrated cognitive neuroscience) then we need to know the function of the re-entrant processing. In particular, it would be helpful to know whether re-entrant processing consists in a fairly much unaltered re-presentation of the same informational content, or whether the content has been or is altered on the second run through. If we couldn't find a difference then we would seem to have some grounds for concluding that (F)early processing can occur at longer latencies[2]. If differences were found, however, then we may have some grounds for concluding that (F)late processing can occur in (A)early locations. The reason to think these are (F)late processes would be that they are incorporating information from association areas such that they may be better thought to be functioning as association areas when they are activated at longer latencies. Since we have strong evidence for those anatomical areas processing (F)early sensory features if differences were found then one might be best to conclude that there is some evidence that a single anatomical location can be involved in both (F)early and (F)late processing[3]. I'm also interested in how the areas performing re-entrant processing deal with first entry processing of basic stimulus features when required to do so *at the same latency* as the re-entrant processes. I'm not sure if one is able to present two different stimuli 1 and 2 and see evidence of which is being neurally processed (or alternatively whether a finding would suggest that both are being processed concurrently on the same neural network). It might be that one kind of process takes priority[4].

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[2]Though inferring no difference on the basis of our not being able to find one is problematic.

[3]I suppose that if differences were found then we would still need to figure out what the re-entrant processes were doing. Another way of attempting to figure this out would be to attempt to disrupt or prevent the re-entrant processing and measure what subjects seemed unable to do in virtue of that disruption. This would seem to risk confounds with effects of the interruption compared with what it was that was being interrupted, however. Perhaps there are methodologies for sorting these issues out, unfortunately I don't know enough about them to feel like I have much that is sensible to offer.

[4]I would expect that sensory processing might take priority as people found that attentional blink stimuli were processed for their sensory features. I am unclear as to whether attentional blink is correlated with a stimuli not being re-entrant processed. It might be that re-entrant processing has something to do with iconic memory, for example.