Monkey See, Monkey Read: Orthographic Processing in Baboons (Papio papio)

Grainger et al., 2012

Notes Okay, so this presentation is based around an experiment that's definitely a learning experiment, but is probably more located in the field of reading, so what I thought I'd do was go over the procedure for the experiment first, just treating it as a learning experiment and maybe seeing what people think about it in those terms, and then get on to the language aspects of it later on.

Notes

Word Recognition and Lexical Decisions

- Pretty simple task: present a word, ask the subject "is this a word?"
- The "no" trials are nonwords: character strings that don't form real words

Notes The basis of a lot of reading research has been the lexical decision experiment, where you basically present a subject with a string of characters and ask them "is this a word?". The words are presented along with nonwords, strings of characters that are hopefully similar enough to words that you can't immediately dismiss them. Accuracy is generally high enough that you can't really get much useful information from it, so what you're typically measuring is reaction times.

Notes

Levels of processing

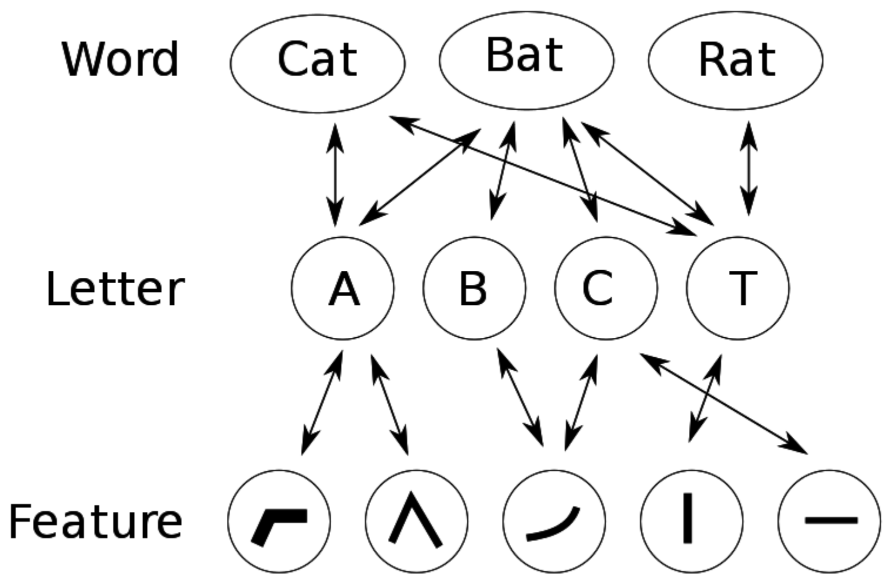


Figure 1: Interactive activation model- McClelland and Rumelhart, 1981

Notes What I think the lexical decision task is basically trying to achieve, and the reason why it's used so widely, is that when you have two groups of words differing on some dimension that you want to compare, making a lexical decision about them hopefully requires subjects to process them to the point where they're accessing information about *words*, not just strings of letters.

So here I've got a simple diagram of the classic interactive activation model, which is showing the levels of representation that visual information passes through when you're reading a word- seeing a word activates letter features, which activates letters, which activates word representations. By the time you've got to this point, I think you're mostly assuming that you've only recognized the word, not necessarily activated its meaning- different theories have different things to say about how much meaning or phonology feeds into this word recognition process. But the idea is that if readers are processing the things they're seeing up to this level, they're matching them up to the set of words they know.

Notes

Does the lexical decision task actually require this?

- Do you need to access your internal representations to make decisions about:
  - 'COOK' and 'XUNQ'?
  - 'LEAP' and 'RIST'?

Notes So at this point, the main question you're left with, is does the lexical decision task actually involve that level of processing? And that's what the experiment I'm going to talk about gets at.

Notes

Teaching monkeys to read

- 6 socially-housed baboons with no prior exposure to written language
- Starting testing sessions whenever they want.
- Testing sessions are blocks of 100 trials: all monkeys did 40,000+ trials across the whole experiment

Notes So here's the experimental setup that Grainger and his colleagues were using: there are 6 baboons with microchips in their arms, and they have free access to computer testing booths. I think in the actual monkey habitat there are lots of monkeys, all potentially part of different experiments at different times, so when they enter a booth, the microchip identifies them and the computer sets up the appropriate experiment. This seems to work fairly well: in the one and a half months that the experiment ran for, all the monkeys did forty to fifty thousand trials.

Notes

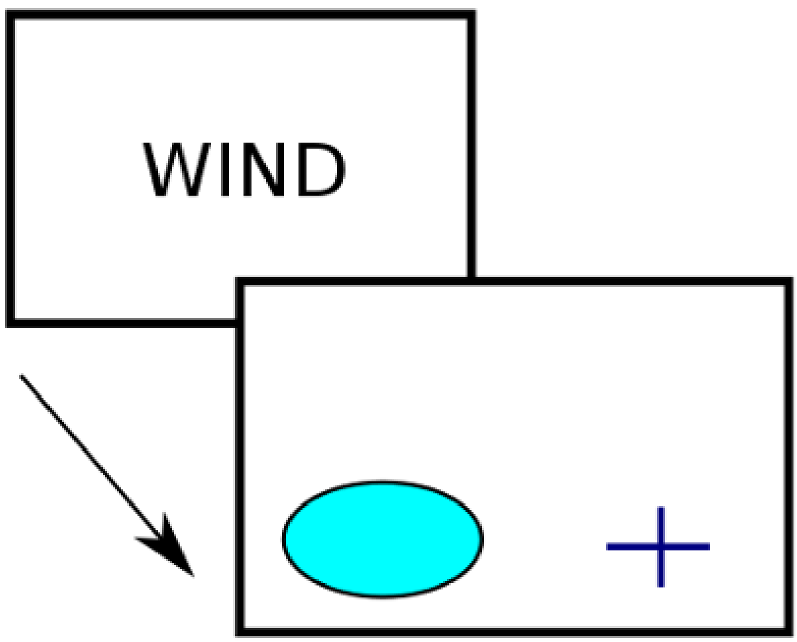


Figure 2: Outline of each trial

Notes Each trial is a lexical decision, very similar to how a lexical decision task works for human subjects: a word is presented, then an oval and cross appear, where the oval is the word response and the cross is the nonword response. When the baboons respond, they either get a wheat biscuit or a they see a green screen for a few seconds.

Notes

Testing blocks

Each 100 trial block consists of:

- 25 presentations of a new word
- 25 previously learned words
- 50 nonwords

Words are considered learned when the monkey reaches 80% accuracy for that word within a block.

Note: for the baboons, a word is something they've seen before, a nonword is something new (or only seen very rarely).

Notes So within each 100 trial block, there's a new word to learn that is presented 25 times, 25 words that are randomly chosen from the set of words the monkey has already learned, and 50 nonwords, randomly chosen from a pool of 7,000+.

Notes

Example words and nonwords

Words	Nonwords
born	sner
make	onfs
pane	knec
week	hilb
limp	grig

Notes So, here's some examples of the words that the monkeys are learning in this experiment, and we'll come back to exactly how these were constructed later.

Obviously words are being seen much more often than nonwords, which are only going to be seen every once in a while, so from the baboon's perspective, what they're responding to is basically a string of characters they've seen before.

As they start to learn the new words, which they've defined as reaching 80% accuracy, these words are added to the pool of words that they've already learned, and a different word is brought in as the novel word to learn.

Notes

The Overall Results

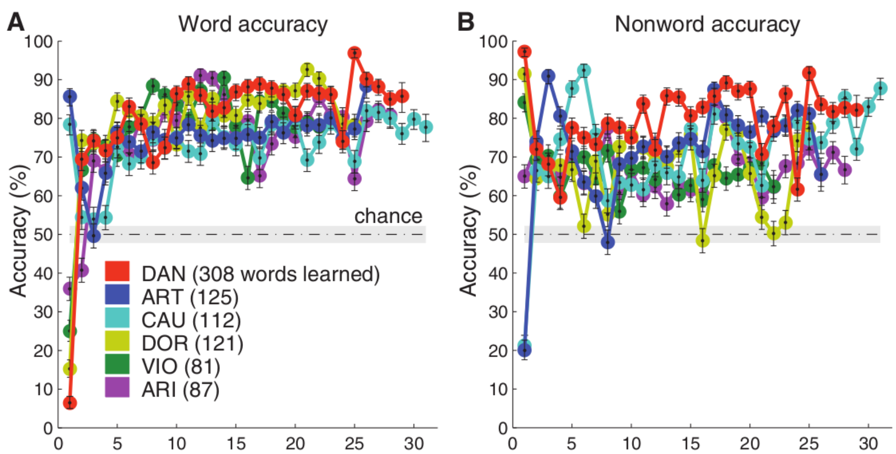


Figure 3: Results graph from Grainger et al., 2012

Notes Okay, so we've covered the basic design, and this point I want to kind of jump ahead to the results, because although this graph is sort of the main result in terms of the monkeys learning to do the task, it's actually not necessarily the most interesting part of the experiment. So, basically, the monkeys are able to learn this task to a decent degree of accuracy: they tend to start off just making one response, but they're fairly quick to actually learn to respond correctly to previously seen versus novel stimuli.

Notes

Some preliminary conclusions

- Monkeys are capable of learning the kinds of detailed visual information that is required for reading.
- Human reading might be built on capacities that were already present in chimps, rather than abilities that were evolved more recently.

> The primate brain might therefore be better prepared than previously thought to process printed words, hence facilitating the initial steps toward mastering one of the most complex of human skills: reading

Notes Even from these broad results, there's some quite interesting conclusions you can draw- the most important thing these results show is that our capacity for reading is probably based in large part on capacities that were already present earlier in our evolutionary history. One of the things that's quite interesting about reading is that it appeared so recently and spread so quickly that it's not likely to be something that's evolved through being specifically selected for, there isn't really enough time for that to have occurred. So this goes along with what a lot of people have been saying about reading and human language more generally- it builds on capacities that were evolved for other purposes.

Notes

The interesting parts

- Towards the end, monkeys were more likely to classify novel real words as words.
- Monkeys obviously aren't making decisions about these stimuli based on whether they're "real English words"
- So, what sources of information *are* they using to make these decisions?

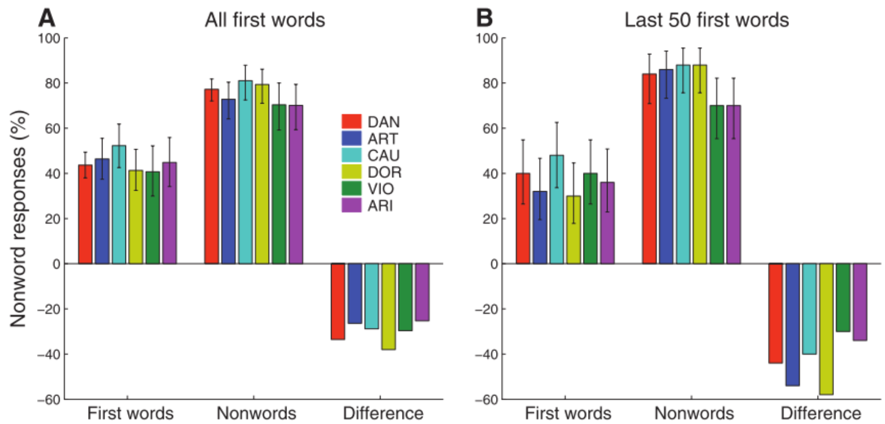


Figure 4: Responses to new words

Notes So, now we're getting to the parts of the experiment that are more interesting from a language perspective. As well as learning to respond "word" to stimuli that they'd already seen, the baboons seemed to learn something about what words and nonwords look like, because when new words were presented for the first time, the baboons were more likely to classify them as words than novel nonwords. The reason they're able to do this has a lot to do with the specific way the nonwords and words in this experiment were chosen, so I've sort of cheated by witholding that from you up to now.

Notes

Word-like words and nonword-like nonwords

Bigrams: `wasp -> wa, as, sp`

Bigram frequency: how often each pair of letters occurs in English words/text.

- Mean bigram frequency for words in the experiment: 3.6×10^{-4}
- For nonwords: 5.96×10^{-5}

Notes One of the simplest ways you can measure "wordlikeness" for these purposes is to look at the "bigram frequency", how often each pair of letters occurs in English words. This is a very simple way of quantifying how a string of letters compares to real English text, but it's surprisingly effective.

The words and nonwords in this experiment were specifically chosen so that their distributions of mean bigram frequency had no overlap, so if the monkeys *were* able to pick up on this statistical difference in the stimuli, that probably helped a lot in their ability to make some kind of guess about novel words and nonwords.

Notes

Statistical structure in language

- Language is too complex and inconsistent to be easily captured by rules
- *But:* there are clear patterns and consistencies that appear when you examine large amounts of text.

Notes What this is getting at is there are some fairly consistent statistical patterns in language that are probably making it more learnable. If you look at any large sample of text (here I've got Moby Dick, because it's an obvious place to get a lot of words), you'll see consistent (but not necessarily identical) patterns in which letters are paired together, which words are paired together, and so on.

Notes

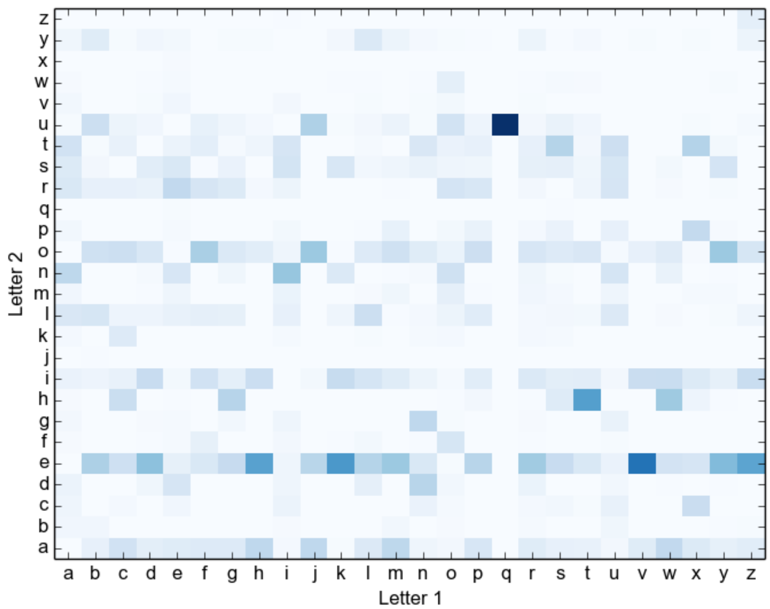
Letter probabilities

From bigram counts, you can get the conditional probability of letters, given the letter that came before them:

$P(L_2|L_1) = \frac{\text{Count}(L_1,L_2)}{\text{Count}(L_1)}$

And you can extend this approach up to trigrams, 4-grams, and 5-grams:

$P(L_3|L_1,L_2) = \frac{\text{Count}(L_1,L_2,L_3)}{\text{Count}(L_1,L_2)}$



Notes What's important about this kind of table is it's not just a summary of the text you fed it: it's a probability distribution, you can actually feed new text into this distribution, and the probability that it gives you back is telling you something like "How likely is it that this string of letters comes from an English word?".

Notes

Diaconis, P. (2008). The Markov chain Monte Carlo revolution. Bulletin of the American Mathematical Society, 46(2), 179–205.

Notes So one fairly cool application of this kind of probability distribution is that you can use it to break simple codes- in the article I've referenced here, they actually give an example where they were contacted by police, who had this coded message that had been sent from one prisoner to another. What's going on here is that you assume that's a simple substitution cipher where each coded letter maps to one real letter, you start with a random mapping, and then you randomly swap two letters in the mapping, and see if that improves the fit of the text to the probability distribution.

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 200 ES ELOHRNDE OHRNO UOVEOULOSU O UOVEO HR OITO HEOQAET IUSOPHE HELO ITOSUVDEL
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1000 IS ILOHANMI OHANO RODIORLOSR O RODIO HA OETO HIOQUIT ERSOWHI HILO ETOSRDMIL
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Figure 5: Codebreaking with bigram frequencies

Notes

Notes So here I've tried to apply a pretty basic version of this approach to the stimuli in the Grainger experiment, and you can see a pretty clear difference in the trigram-based probabilities of the words and nonwords. These probabilities are just based on the kind of conditional probabilities I showed above, where to get the probability of any particular trigram, you just count how many times you've seen that trigram, and divide it by the number of times you've seen the starting bigram. So this model isn't storing any information about whole words, but it's able to make this distinction between words and nonwords.

Notes

Back to humans

- Baboons seem to be able to build up some sort of memory for which letters follow which letters, and make lexical decisions based on this.
- How do we know that humans aren't doing this?
  - Human studies deliberately use nonwords that are more similar in bigram frequency

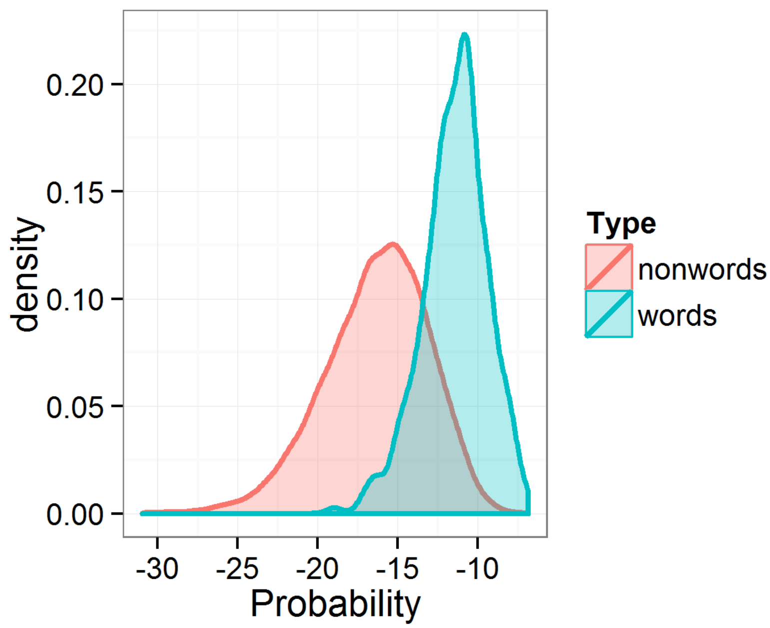

Figure 6: Trigram probabilities for the stimuli in the Grainger experiment

- But: even if you choose a good automated process for choosing nonwords, the nonwords can end up similar to each other, because they're being generated by the same process (see Keuleers and Brysbaert, 2011)

Notes So bringing this back around to what I was talking about right at the start of the lecture- how do we know that human subjects doing lexical decision tasks are responding based on their word knowledge?

Notes

Finally

Youtube video of the experimental setup