

Internal clocks and the  
perception of time...and maybe  
some other things as well...

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What is time? St. Augustine was  
confused....

- “When no-one asks, I seem to know, but when someone asks me what it is... I realise I don’ t know at all”
- ...and he wasn’ t the only one!

J.J. Gibson even said...

- “Events are perceivable, but time is not”

**THE END**

Thanks for your attention

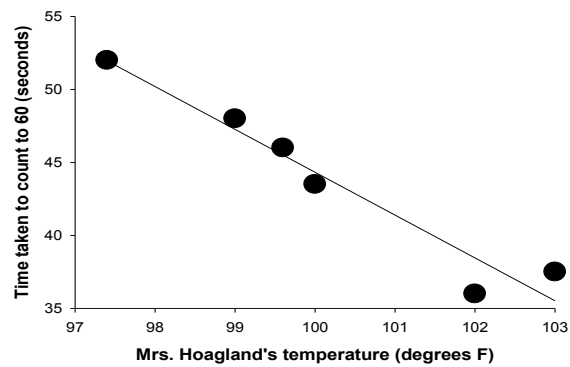
## Internal clocks

- The idea that humans possess an internal clock on which (some) timing judgements are based dates back at least to the 1920s
- In English-speaking Psychology, the name of Hoagland is usually associated with this idea, but a French researcher, Francois, actually predated the ideas of Hoagland

## Temperature and “chemical” clocks

- Chemical reactions go faster when heated, so your chemical clock should “tick” faster when heated up
- Hoagland noticed that his wife had “distortions” of time when she had flu

## Mrs. Hoagland



## What this shows

- The hotter Mrs. Hoagland was, the faster she counted
- put another way, her “estimate” of what one second was became *shorter* when she was heated up
- This is consistent with a “speeded up” chemical clock

## Body temperature and time estimation

- Many methods were used
- Heated rooms, heated helmets, natural fevers, bicycles in tanks of water.....
- Wearden and Penton-Voak (1995) reviewed the results

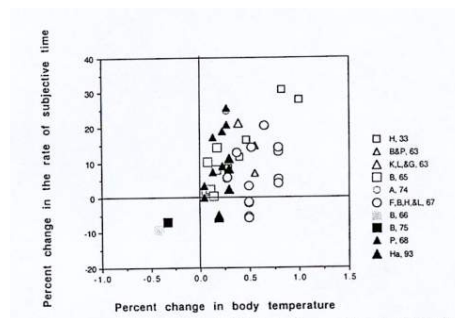
## Wearden and Penton-Voak

- We took all the studies up until 1995 (... although we missed one!)
- Increases and decreases in the rate of subjective time were plotted against increases and (more rarely) decreases in body temperature

## Hypotheses

- **Increases** in body temperature should produced **increases** in the rate of subjective time
- **Decreases** in body temperature should produce **decreases** in the rate of subjective time

....and that's what (usually) happened.....



## Clock models

- The basic model has been that of a **pacemaker-accumulator** clock
- this consists of
- a pacemaker which generates pulses
- an accumulator which stores them
- a switch which connects the two

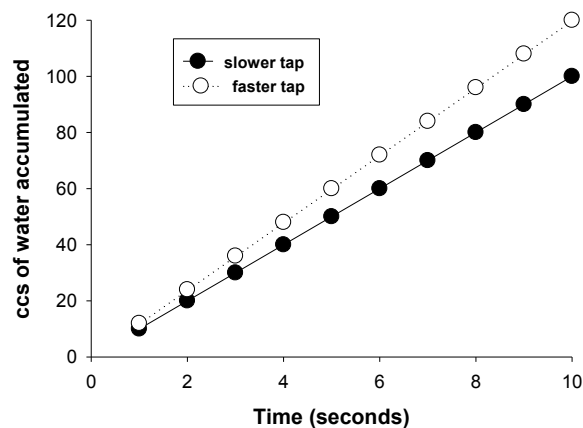
## An intuitive example...

- We use the water flowing from a tap as our pacemaker
- ....and a jug as our accumulator
- To begin and end timing we open and close the tap (...it's a switch....)
- The quantity of water accumulated is our measure of time

## ...two taps

- We have two taps and two jugs
- One tap flows faster than the other (let's assume everything else is the same)
- One tap flows at 10 cc every second
- The other at 12 cc every second
- ....what happens with our two taps and jugs?

## Two taps



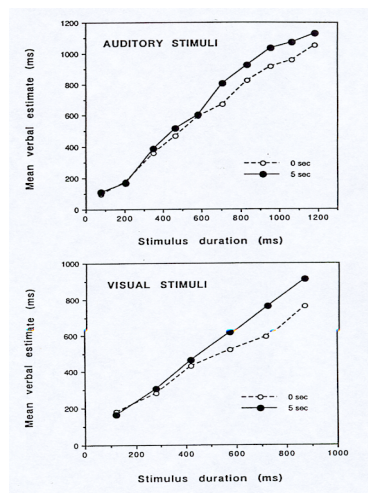
## Things to note

- The difference between the amount accumulated over time in the two jugs gets bigger as the time gets longer
- ...the difference between the amount accumulated is a **slope effect**
- such slope effects are evidence for...
- ...a pacemaker-accumulator clock in general
- ...”speeding up the clock”

## Click trains

- Treisman and colleagues proposed that accompanying stimuli by trains of clicks “sped up” the pacemaker that was used to time them, so made the stimuli seem longer
- Replicated by Penton-Voak et al. (1996)
- Replicated more recently by implication by Burle and Bonnet, and Burle and Casini

## Effect of click trains



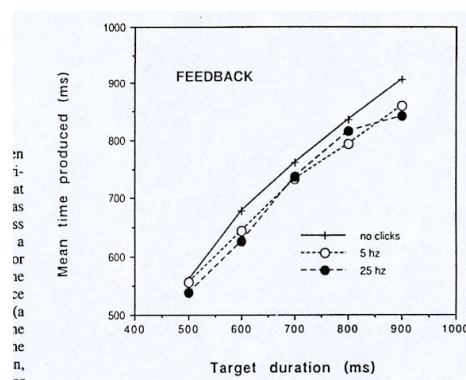
## Click trains

- If click trains make the pacemaker of the clock run faster, it's just like having a faster-flowing tap...
- ...you'd expect a **slope effect**...
- ...and that's what you get

.....however

- Although verbal estimates increase with a “speeded up” clock...
- ....times produced **decrease!** (remember Mrs. Hoagland)

## Results



## Why? Let's count ticks...

- Suppose that the clock usually ticks at 50 per sec, and the “speeding up” changes this to 60 per sec
- If a person produces 1 sec by counting 50 ticks, then the time produced in the speeded up condition will be 0.83 sec (50/60)
- ....and this sort of thing is what happens

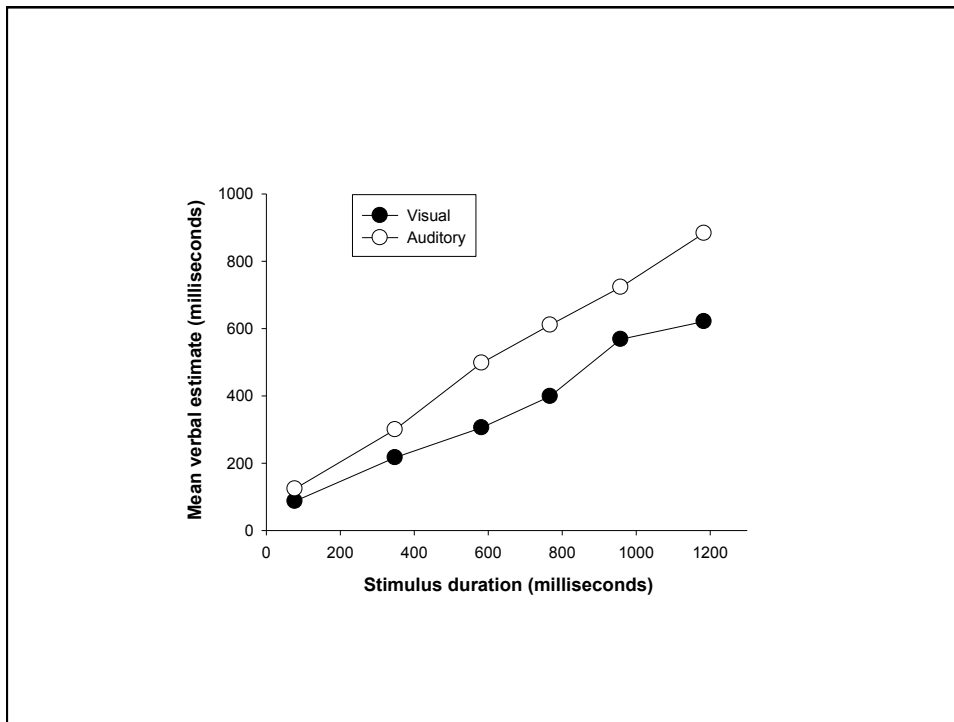
## “Tones and lights”

- Another area where the idea of an internal clock seems to work well is in explaining modality differences
- “Tones are judged longer than lights”
- ....in other words, auditory stimuli appear to last longer than visual ones of the same duration

## How to explain it

- The tones and lights effect has been known since the 19th. Century
- Many studies don' t attempt any explanation
- Wearden et al. (1998) proposed that the difference is (mainly) pacemaker speed, which is faster, for some reason, for tones than for lights

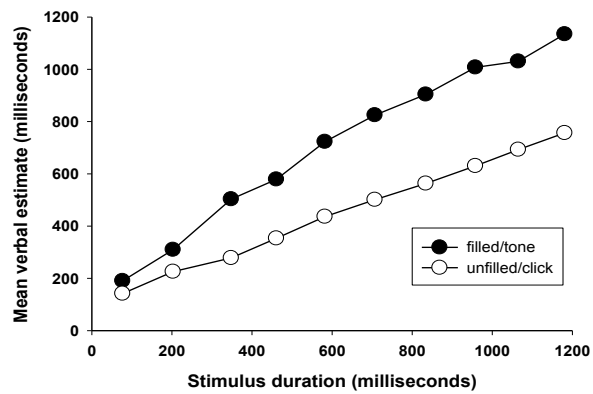
- This interpretation predicts that the tone/ light difference is a slope effect (greater at longer durations than shorter ones)
- ...and this is true...



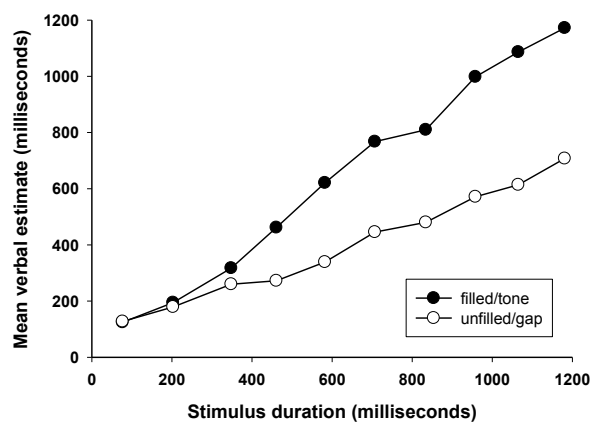
## Filled duration “illusion”

- It's also been known since the 19<sup>th</sup> Century that a filled interval (one filled with a continuous stimulus) will be perceived as longer than an unfilled or empty interval (such as one started and ended by brief clicks or flashes)
- Maybe this is a “slope effect” too?

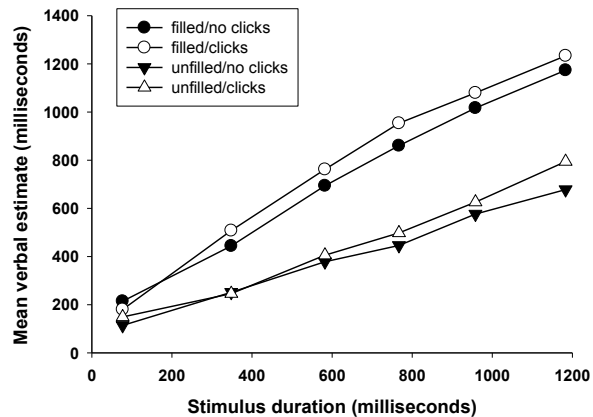
It is when the stimuli are tones and click-defined intervals



...and it is with tones and gaps in tones



## The famous click trains can even “speed up” unfilled intervals



## Linear or non-linear timing?

- The pacemaker-accumulator model suggests that the “growth of time” is linear
- On average, in some time  $nt$ ,  $n$  times as many ticks accumulate as in time  $t$ , whatever  $n$  is (i.e. the accumulation can be scaled up to longer intervals or down to shorter ones)

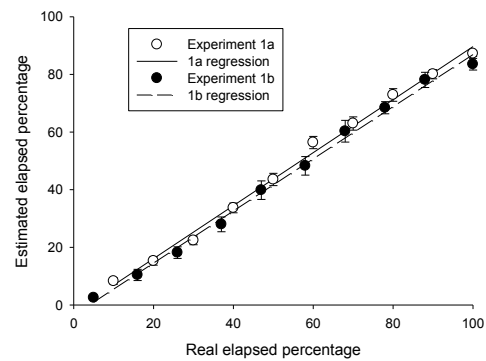
## Problem

- Deciding between linear and non-linear time scales is very difficult (ask me why later, if you're interested), but one (possible) way is to compare judgements of **part** of an interval with judgements of the **whole** interval

## “Fractionation” experiment

- People were given time intervals that lasted 10 seconds (but they weren't told how long they were), identified as standards, with counting prevented by a secondary task
- Then they received different durations, 1 s , 2 s....etc., up to 10 s, and had to say what fraction the comparison duration was of the standard
- In another experiment, because of a programming error, all durations were 0.5 s less than they were supposed to be

## Results



## Comments

- Although the “fractionation” wasn't perfectly accurate, there was no evidence of non-linear relations between the time judgements and real time values

## So far...

- You've seen how the idea of a pacemaker-accumulator clock can account for modality effects, and linear time scaling
- You've also seen examples of speeding up the clock (and this can be done with children too, but the procedure is too complicated to discuss)...
- The clock can also be "slowed down" in order to test anecdotes about arousal and subjective time

## "Arousal" and subjective time

- An old idea is that the rate of the pacemaker of the internal clock is linked to a person's "arousal" level: going faster when arousal is increased above normal and slower when it is decreased below normal

## Anecdotes

- Many anecdotes report that external time seems to “slow down” (i.e. external events seem to last longer than normal) in “emergency” situations, such as car crashes and military conflicts
- This is consistent with a highly speeded up pacemaker....
- ....but how can we explore such effects in the lab?

## Wearden (2008)

- I decreased arousal basically by making the experiment incredibly boring....
- This caused a fall in rated arousal
- And also caused subjective time to, apparently, slow down
- You’ ll have to read the article, which is in the *Quarterly Journal of Experimental Psychology*, 61, 264-275

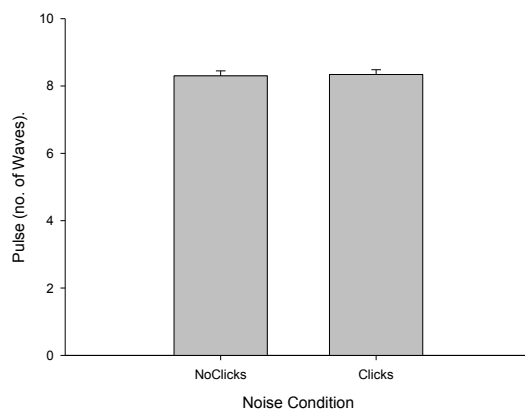
## Are the clicks really arousing?

- A 5 s train of clicks certainly doesn't seem to be arousing in the everyday sense of the word...
- ...but maybe it has subtle physiological effects that can be detected
- I looked at this some years ago but recently...

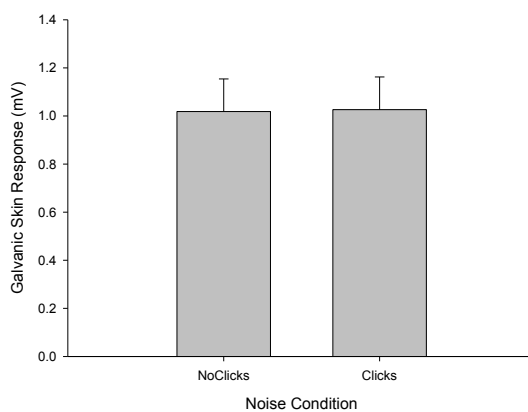
## ....Allely and Jones did it properly

- They took some physiological measures during the clicks and the tones which followed them
- The total event length was 6800 ms (5 s of clicks, plus the longest possible tone length)
- Measures were pulse rate, GSR, and EMG in the eye and mouth region (but only eye data are shown)

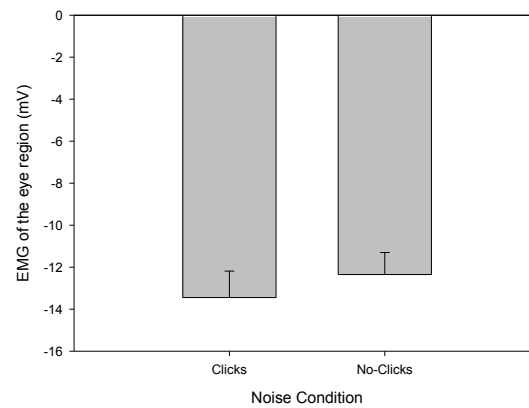
## Pulse rate



## Galvanic skin response



## EMG



## Clearly...

- ...there were no significant differences between the conditions in any measure..
- ...even though time estimates differed, as usual

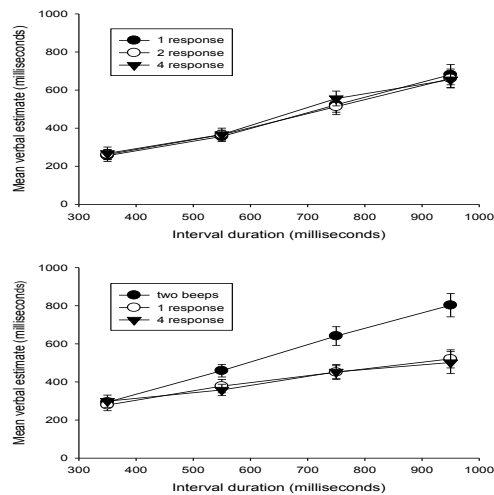
## The story so far

- You've seen how the idea of a pacemaker-accumulator clock can account for a lot of data
- Results often seem almost supernaturally in accord with the predictions of the clock model
- But ... "what's an internal clock for?"
- Or, more generally, what kind of processes is subjective time involved in?

## Subjective time and other things

- Subjective time seems to be implicated in some processes that don't seem to be intrinsically temporal
- One of these is "agency"
- If we ask people to estimate the gap between a response they make and the consequence of that response (e.g. a beep), then the time is judged as shorter than between two beeps that the computer produces

## Agency effect



## The agency effect..

- ....looks like something you've seen before
- If we define the *agency effect* as the difference between the estimates in the agency and two beep conditions, then this estimate difference gets bigger as the time between the events gets longer
- This is like “slowing down the clock”

## Which comes first?

- Is the agency effect *primary* and the subjective time effect *secondary*? That is, do people decide whether they've caused the event or not, *then* make the time judgements
- Or, is the change in subjective time the mechanism (or part of the mechanism) by which causality is detected?
- Remember Pavlovian conditioning....

## Other connections

- Time is implicated in many psychological processes not thought to involve time estimation, such as memory loss over time, extraction of information from visual displays or auditory streams, visual search....and many others
- In general, having “more time” improves performance on lots of tasks
- Here's a really hard question...

- Do psychological processes take place in real (i.e. clock-measured) time or subjective time?

- Suppose that in 60 seconds you can read 60 lines of text
- If the 60 seconds is made subjectively longer can you read (a) 60 lines, as before, or (b) more than 60 lines?

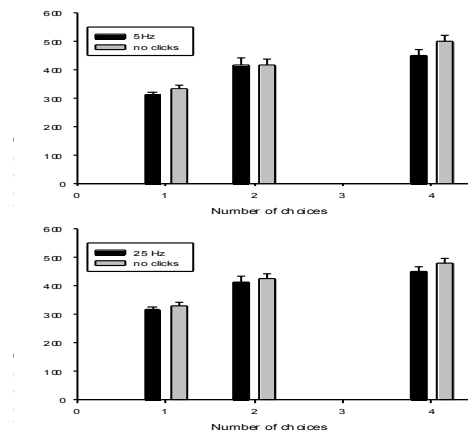
## ...continued

- Suppose that in a display lasting  $t$  seconds you can extract  $X$  items
- If the subjective duration of the display is lengthened can you extract (a)  $X$  items or (b) more than  $X$ ?
- The answer (b) in both cases implies that (i) psychological processes take place in subjective time, rather than real time, and (ii) consequently, there's a deep connection between subjective time and information processing

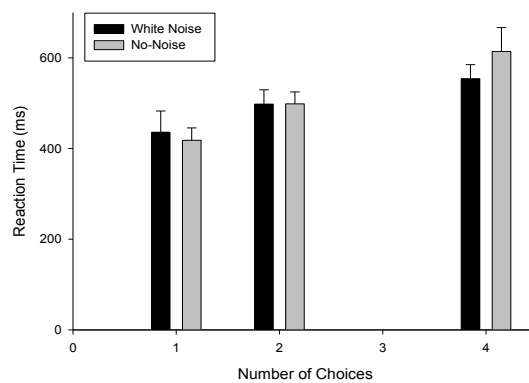
## Experiments

- Jones, Alleley, and Wearden (2011) looked at the effect of click trains (and sometimes a control white-noise condition) on a number of psychological processes
- The first was single-response and choice reaction time
- Are people really “sped up” by the clicks (i.e. faster than without clicks)?

## Effect of clicks on simple and choice reaction time



## Effect of white noise on reaction time



## Results

- The results show that the click manipulation, which “speeds up” subjective time, makes reaction times generally faster, whereas the white noise (which doesn’t change duration experience) has little or no overall effect

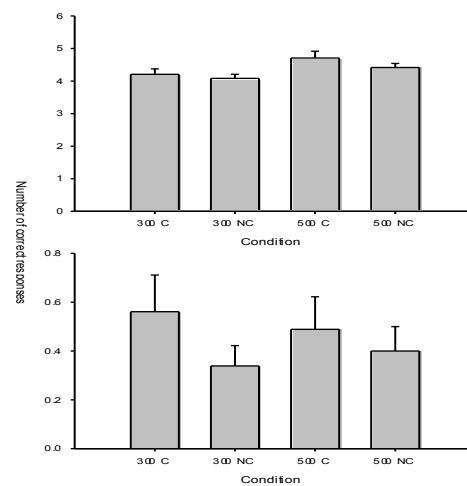
## But...

- Maybe we’ve just sped up motor responses
- What happens if we look at a task which doesn’t depend on motor speed?
- We used a simplified version of the classic Sperling iconic memory task

## Procedure

- People received a display lasting for either 300 or 500 ms, followed by a mask, and had to report items from the display
- The display was either preceded by clicks or not

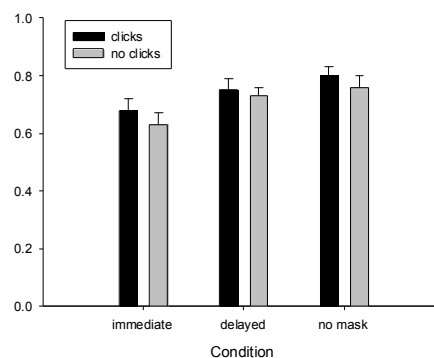
## Results



## Results

- More items were remembered correctly after clicks, although there was (annoyingly) an increase in false alarm rates too
- We then did a longer-term recognition memory experiment
- People received 80 pictures followed by an immediate mask, a delayed mask, or no mask. In each case the pictures were either preceded by clicks or not
- Later there was a recognition test, with the original 80 pictures mixed in with another 80
- The task was to identify the previously-presented pictures

### Results: more items recognised after clicks



## Comments

- The results strongly suggest that ....
- ....psychological processes take in subjective time, as “speeding up” subjective time appears to (i) make reactions (really) faster and (ii) give people more time to process information

## But...

- Do click trains always improve/change performance?

## Clicks: time, length, and number

- Sylvie Droit-Volet has 2010 paper where she's looked at the effect of clicks on time, number, and length
- She used a bisection technique for all these experiments

## Bisection

- In a bisection task, people are initially presented with Short and Long standards (e.g. tones 2 and 8 s long, lines 2 and 8 cm long, 2 dots or 8 dots)
- Then, people receive intermediate stimuli (e.g. 2-8 s, 2 to 8 cm lines, etc.) and they have to classify these in terms of similarity to the Short and Long standards

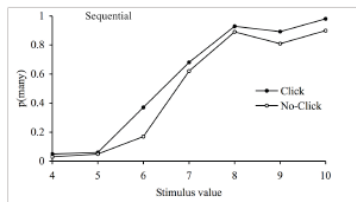
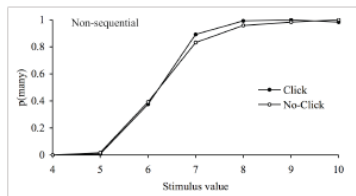
## Sequential and non-sequential presentation

- Sylvie's experiment presented the standards, then gave the comparisons with and without clicks
- But she also had "sequential" and "non-sequential" presentation
- Sequential was, for example, when you had a series of small lines that you had to total in length, or a series of dots where you had to add up the number
- Non-sequential was when you get the stimulus all at once

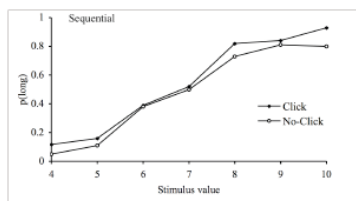
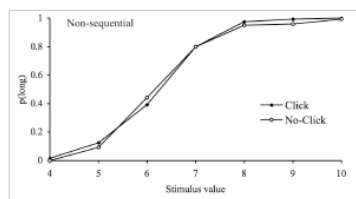
## The clicks...

- ...made durations subjectively longer whether they were sequential or not
- But for length and number the results were different

# Number



# Length



## Conclusion

- Duration is “necessarily” sequential
- But length and number are only affected by clicks when they’re presented sequentially
- Maybe the click trains aid some sort of “sequential binding” of the components
- But this is strange, as increasing the subjective time between the components would tend to make them *less* associated

## ....continued

- Perhaps the clicks affect “accumulation” of different sorts of quantities, so the effect is only noted when whatever it is that’s being measured accumulates
- Models of reaction time like Ratcliff’s assume some sort of accumulation of information, so if this process is faster reaction times will be shortened

## ...continued

- Perhaps there are “time-like” quantities (which accumulate), and “non-time-like” ones which don't
- So “sequential” length and number are time-like, but “non-sequential” versions of these quantities aren't

## How the clicks affect the brain

- Well, we don't know, but one possibility is that they synchronize neural activity, so that signals are perceived against a more coherent background than when neural activity is “more random”

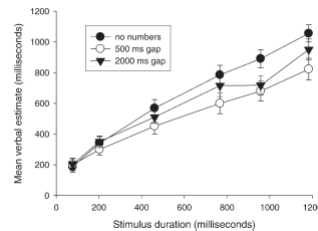
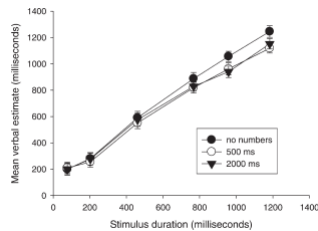
## Time and “processing”

- In general, there seem to be links between manipulations which change subjective time and those which change “processing”
- More (subjective) time makes processing better (in various ways).
- Does it work the other way around?

## Task-switching

- Wearden et al. (2010) asked people to add up rapidly-presented digits then estimate the duration of a tone, or a visual stimulus
- This is a sort of “task-switching” between a non-timing task (addition) and a timing task (estimation)
- What happened?

## Results: tone (left), square (right)



## Comments

- The task switch made subjective duration shorter, but the effect was like a “slowing down” of the clock, not a “late start”
- Task-switching of the normal ABABAB type finds longer RTs for B than in BBBB, so “processing” is worse after a switch
- Caution: the Wearden et al. (2010) work isn't conventional task switching

## In addition...

- There are some other examples of situations in which time judgements and “processing efficiency” seem to go in the same direction: “faster time = better”, “slower time = worse”

## In conclusion

- You’ve seen how useful the idea of an internal clock of a pacemaker-accumulator type has been
- It can help understand modality effects on timing, effects of clicks, and other manipulations of subjective time
- The “internal clock”, or some mechanism for measuring subjective time, appears to be deeply connected to more general information processing (although we aren’t completely sure how!)

## Thanks

- To Luke Jones, Clare Alleley, Sylvie Droit-Volet, and innumerable students who've conducted experiments for me
- No thanks at all to the BBSRC and ESRC who have persistently turned down grant applications for this, and other, time perception work