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Cognitive Psychology Topics

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An independent academic psychologist, based in England, who has written extensively on different areas of psychology with an emphasis on the critical stance towards traditional ideas.

A complete listing of his writings at http://psychologywritings.synthasite.com/.

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1. SUBJECTIVE DURATION

1.1. INTRODUCTION

Perception of time duration fluctuates. "For example, upon first glance, the second hand of a clock sometimes seems to be frozen in position momentarily before it continues to tick at a normal pace [1]. Perceived duration can be warped by saccades, flicker, and life-threatening events, which are sometimes anecdotally reported to unfold in slow motion" (Pariyadath and Eagleman 2007 p1).

An experimental technique to study this phenomenon is to present the same stimulus repeatedly in quick succession. In this situation, the first presentation is reported as longer duration by participants (despite the objective duration being the same) (known as "duration dilation") (eg: 50% longer for visual stimuli; eg: Rose and Summers 1995).

An overestimation of duration also occurs if an "oddball" stimulus is presented in the middle of the repeated presentation of the same stimulus ("oddball illusion"; Tse et al 2004 [2]). Tse et al (2004) called this duration dilation "time's subjective expansion".

1.2. PARIYADATH AND EAGLEMAN (2007)

What does "time's subjective expansion" mean in relation to different senses at the same time? Pariyadath and Eagleman (2007) considered two answers to this question:

i) Here "perception works like a movie camera: when one aspect of the scene slows down, everything is slowed down. Thus, if a police car launching off a ramp were filmed using slow-motion photography, it would not only have a longer duration in the air, but also its sirens would blare in a lower pitch, and its lights would blink at a lower temporal frequency. In this case, duration,

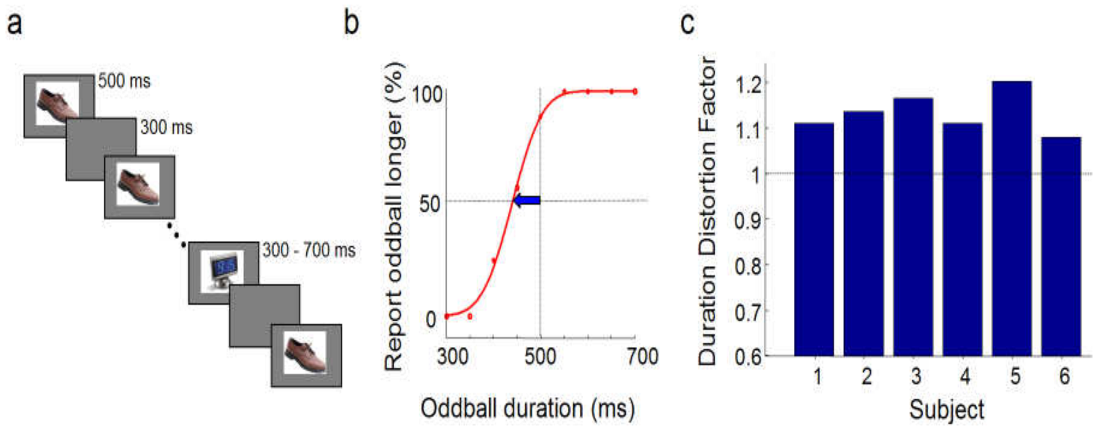
[1] The "stopped clock illusion" or chronostasis.

[2] Also called the "temporal oddball illusion" - "a single oddball (low probability event) seems longer than a single standard (high probability event) of the same duration" (Simchy-Gross and Margulis 2018 p275).

sound pitch and visual flicker all change hand-in-hand" (p1).

ii) Only perception of one sense changes - "Thus, the police car may be judged to have a longer duration in the air, even while the frequencies of its sounds and flickering lights remain unchanged" (Pariyadath and Eagleman 2007 p1).

Pariyadath and Eagleman (2007) set about finding evidence for these two hypotheses with five laboratory experiments. In the first experiment, which tested the "oddball illusion", six participants viewed nine repeated presentations of a photograph with an oddball photograph in the middle (eg: shoe photograph with computer screen photograph as oddball). Participants were asked to report the duration of the photographs (which varied objectively between 300 and 700 ms). The oddball photograph was perceived as staying on the screen for an average of 12% longer than the repeated photograph (figure 1.1).

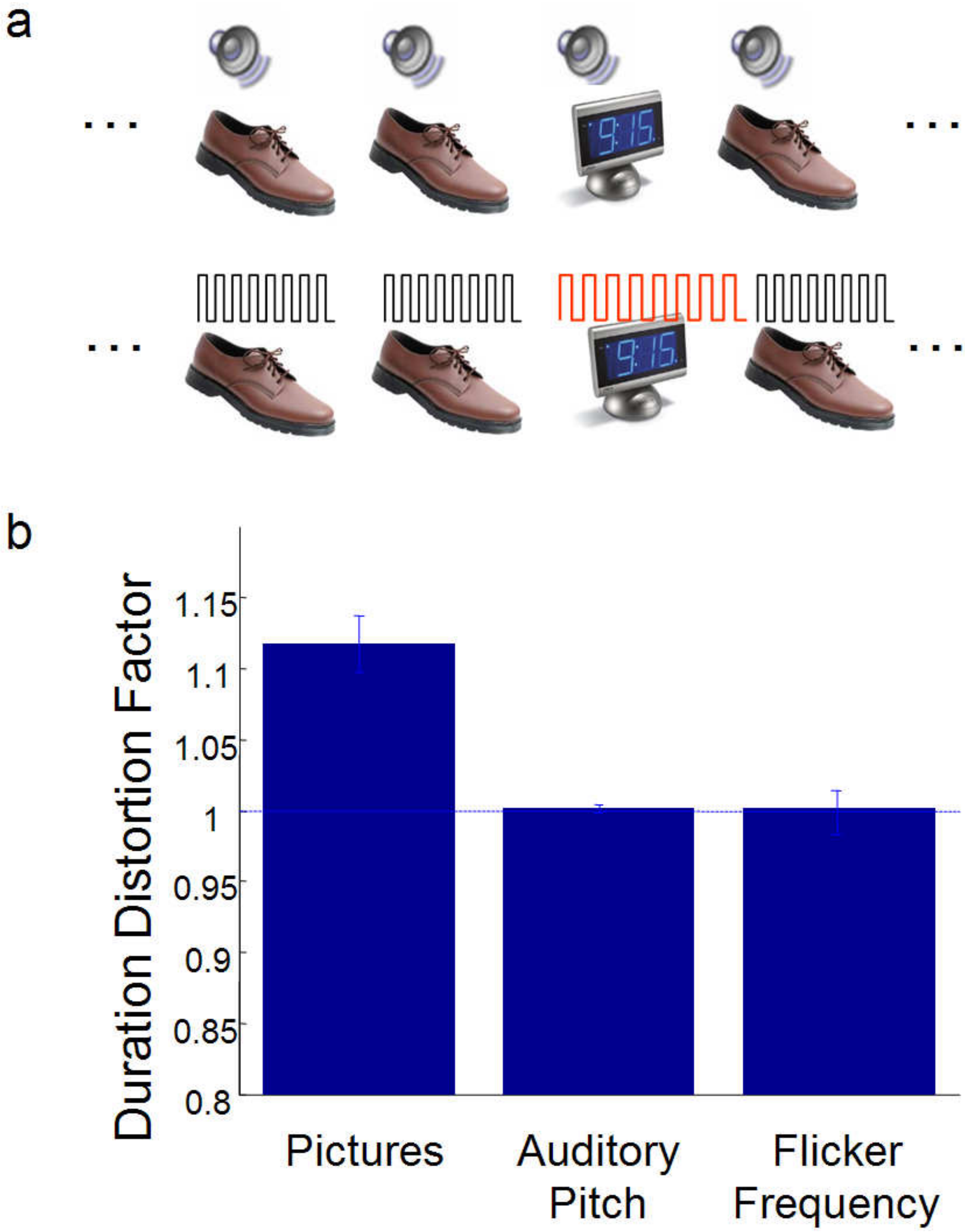


(Source: Pariyadath and Eagleman 2007 figure 1)

Figure 1.1 - Experiment 1 (a) procedure, (b) perceived duration of oddball image based on length of actual presentation, and (c) ratio of overestimation of duration of oddball image for each participant (where 1 = actual duration).

Experiment 2 replicated the previous one, but played a sound when a photograph appeared. If the oddball image is perceived as longer on the screen, will the accompanying sound be perceived at a lower frequency? Pariyadath and Eagleman (2007) answered: "Participants showed no difficulty in discriminating the frequency of the beep accompanying the visual oddball from the beep accompanying the standards... We conclude from this result that the oddball illusion is not accompanied by a concurrent distortion of perceived auditory frequency.

This indicates that it is not time in general, but only visual durations in particular, that slow during the oddball" (p2). When a visual flicker was added, this was not perceived differently with the oddball image (figure 1.2).

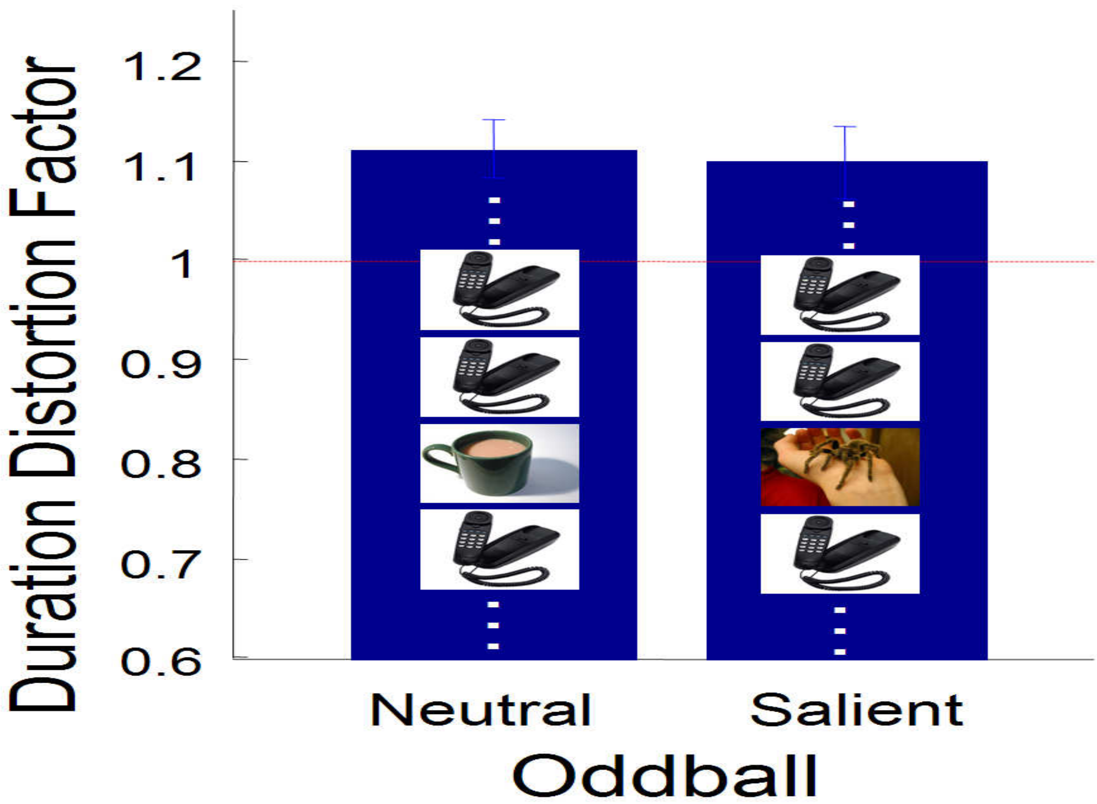


(Source: Pariyadath and Eagleman 2007 figure 2)

Figure 1.2 - Experiment 2 (a) procedure, and (b) mean ratio of overestimation of duration of oddball image, sound and visual flicker (where 1 = actual duration).

How to explain these findings which fit with hypothesis (ii) above? Tse et al (2004) proposed the "pacemaker-accumulator model of timing" to explain duration dilation as a result of increased attention or arousal in relation to the oddball. Time perception is based on an internal clock or pacemaker in the brain. Pariyadath and Eagleman (2007) explained that "an increase in arousal caused by the appearance of an oddball stimulus leads to a transient increase in the internal clock's tick rate. In consequence, the accumulator collects a larger number of ticks in the same period and duration is perceived as progressing slowly while viewing the oddball" (p3).

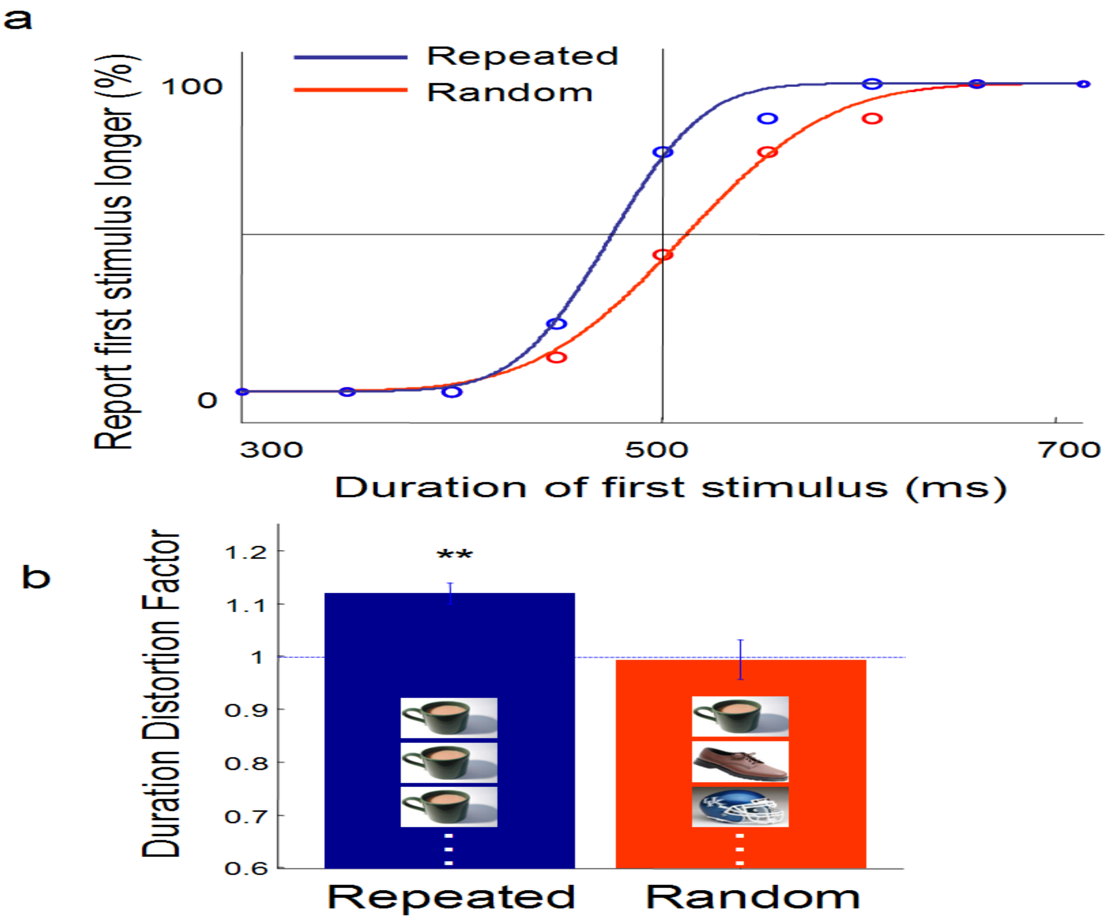
If this theory is correct, then emotionally salient oddball images will produce greater arousal, and thus be perceived as longer than emotionally neutral oddball images. Using the same procedure as previous ones, Experiment 3 included emotionally salient oddball images like spiders or pointed guns, and neutral like a coffee cup. The perception of the duration of the oddball image did not vary between images (figure 1.3). So, the pacemaker-accumulator model was not supported.



(Source: Pariyadath and Eagleman 2007 figure 3)

Figure 1.3 - Mean ratio of overestimation of duration of oddball image based on emotional salience in Experiment 3 (where 1 = actual duration).

Pariyadath and Eagleman (2007) considered an alternative explanation for the oddball illusion linked to predictability. The researchers concentrated on the first presentation of a series of images, which is usually perceived as longer ("the debut effect") [3]. Participants were shown the same image four times or four different images. Pariyadath and Eagleman (2007) stated: "Since the repeated stimuli are more predictable, we hypothesised that the first stimulus would be judged to have lasted longer–perhaps because repeated stimuli would be contracted in duration. In the case of random stimuli, because the succeeding images are not predictable from the first stimulus, no duration distortion would be expected" (p3). This was found in Experiment 4 (figure 1.4).

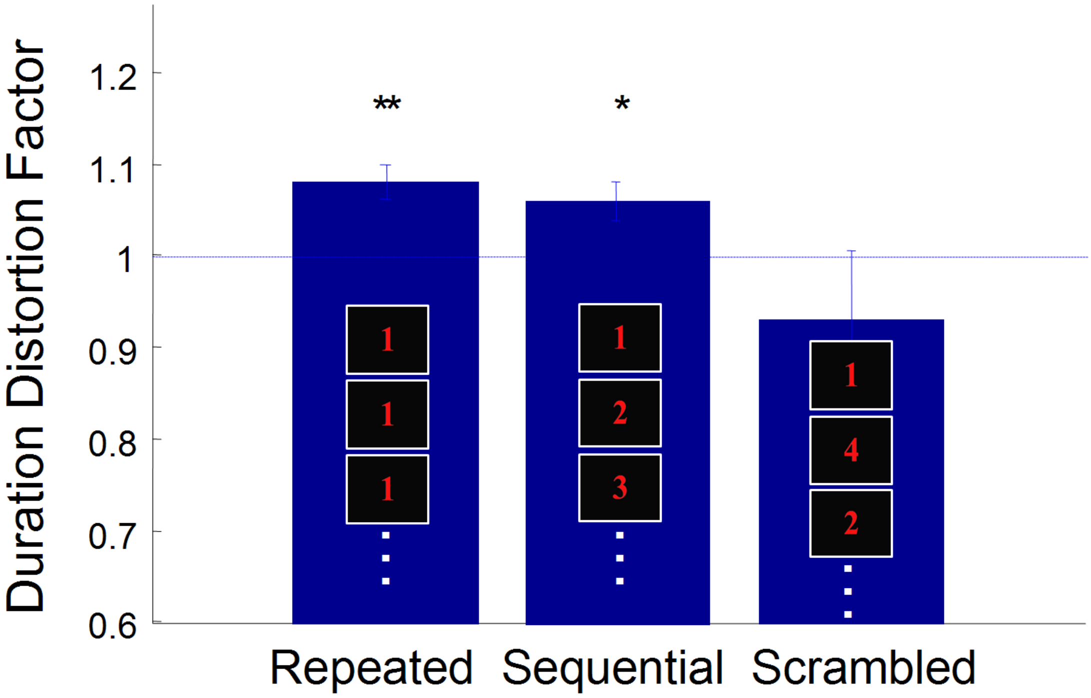


(** = significant difference between groups)
(Source: Pariyadath and Eagleman 2007 figure 4)

Figure 1.4 - Experiment 4 (a) perceived duration of oddball image based on length of actual presentation, and (b) mean ratio of overestimation of duration of oddball image (where 1 = actual duration).

[3] Also known as "the subjective shortening of duration" or "time-shrinking" (Nakajima et al 1992).

The final experiment investigated predictability and the debut effect using numbers. Participants were either shown the number "1" five times (repeated presentation), numbers "1, 2, 3, 4, 5" (sequence), or numbers "1, 4, 2, 5, 3" (scrambled sequence). The perception of the duration of "1" at the beginning of the sequence was measured. The "1" in the repeated presentation was perceived as shown for longer than the other two conditions (figure 1.5).



(** and * = significant difference between groups)

(Source: Pariyadath and Eagleman 2007 figure 5)

Figure 1.5 - Mean ratio of overestimation of duration of number "1" based on other numbers shown in Experiment 5 (where 1 = actual duration).

Pariyadath and Eagleman (2007) summed up (table 1.1): "Our experiments on duration illusions show that subjective time is not a single entity. The oddball and debut illusions involve distortions in duration judgments but do not affect perceived auditory pitch or high visual flicker frequencies. Thus, the oddball and debut illusions do not entail 'time's subjective expansion' as was previously hypothesised. Our results suggest that neural systems involved in timing generally work in concert but are nonetheless separable" (p4). Furthermore, the oddball illusion was not the result of increased attention or arousal, but predictability was involved [4].

No.	Key finding
1	Oddball illusion established.
2	Oddball illusion does not include distortion of accompanying sounds.
3	Emotional salience of oddball stimulus not important.
4	Importance of predictability in oddball illusion with images.
5	Importance of predictability in oddball illusion with numbers.

Table 1.1 - Summary of five experiments by Pariyadath and Eagleman 2007.

These studies involved laboratory experiments in which the researchers could control the variables and the environment (table 1.2). Note how the researchers changed each experiment to increase their understanding of the phenomenon under study. Sometimes this involved excluding certain hypotheses (eg: Experiment 3).

Strengths	Weaknesses
1. Establish cause and effect relationship between variables. 2. Control of participants and variables. 3. Measure behaviour precisely in laboratory. 4. Replication possible because of standardised procedures used, and the comparison of participants.	1. Low ecological validity; ie: artificial study of behaviour. 2. Narrowness of independent and dependent variables. 3. Measures behaviour for short limited period only. 4. Experimenter effects, and demand characteristics and evaluation apprehension.

Table 1.2 - Main strengths and weaknesses of the laboratory experiment method.

1.3. Subsequent Research

Pariyadath and Eagleman (2008) coined the term "proliferation effect" to describe the perception of serially flashed visual stimuli in different locations on a screen as presented simultaneously. But this effect

[4] This explanation has subsequently been called the "coding efficiency hypothesis".

does not occur if the same visual image is flashed repeatedly, "indicating that persistence of vision (and hence subjective duration) shrinks for predictable stimuli" (Pariyadath and Eagleman 2008 p1).

The participants were US adults who viewed letters presented for 10-30 ms. This experiment also confirmed "the debut effect" as the first stimulus in a sequence was perceived as longer (over 100 ms). "Beyond this threshold, stimuli are perceived approximately accurately, ie: close to their true physical duration. Because of visual persistence, the physically present stimulus is accompanied by the 'ghosts' of stimuli that were presented recently. Thus more than one character appears to temporally overlap on screen" (Pariyadath and Eagleman 2008 p3).

In terms of the physiology of duration dilation, "the neural response (firing rates) in higher cortical areas quickly diminishes after repeated presentations of a stimulus..., an effect generally known as repetition suppression. [...] [So] a suppressed neural response corresponds to a shorter perceived duration" (Eagleman and Pariyadath 2009 p1842).

Eagleman and Pariyadath (2009) speculated that "subjective duration might be considered a qualia, a property that is assigned to stimuli in the same way that colour is bound to objects, or motion can be 'painted on' to stimuli by the visual system... In other words, duration may be an attribute that is painted on to interpretations of events in the world" (p1848).

All the experiments mentioned so far used the retrospective time estimation paradigm (ie: estimating the duration after the event). There is also prospective estimation where participants make judgments before the event. Both these paradigms are direct measures of subjective time duration, whereas Simchy-Gross and Margulis (2018) used an indirect measure called "musical imagery reproduction". Participants are asked to imagine an excerpt of music previously heard, and press a button when they start and finish. "Importantly, participants completing a musical imagery reproduction are not explicitly asked to estimate duration or time. Thus, making a musical imagery reproduction involves focusing attention on music and its inherent properties, such as pitch and timbre, rather than the duration of an interval" (Simchy-Gross and Margulis 2018 p276). This method has been found to mirror the actual duration of melodies (Simchy-Gross and Margulis 2018).

Simchy-Gross and Margulis (2018) investigated whether an entire sequence of oddballs seems longer than an entire sequence without oddballs using auditory tones.

Experiment 1 - Fifty-five US undergraduates listened to coherent or incoherent (oddball) chord sequences of 7-12 seconds before imagining the chord sequence in their heads or stating the length of the sequence. Verbal estimates of the sequences containing oddballs were shorter, but the imagined oddball sequences were longer (table 1.3).

	Verbal Estimates	Imaging Duration
Oddball sequence	0.93	0.97
Coherent sequence	0.96	0.94

Table 1.3 - Mean ratio scores for time estimation in Experiment 1 (where 1.00 = actual duration).

Experiment 2 - Fifty-seven more undergraduates listened to coherent or incoherent chord sequences, but half of the sequences were familiar (ie: heard before). Subjective duration was measured by imagining the chords only. The familiar oddball sequences were perceived as shorter whereas the unfamiliar oddballs were perceived as longer (table 1.4).

	Familiar Sequence	Unfamiliar Sequence
Oddball sequence	0.91	0.93
Coherent sequence	0.95	0.90

Table 1.4 - Mean ratio scores for time estimation in Experiment 2 (where 1.00 = actual duration).

To sum up: "The sequences that contained oddballs sometimes seemed longer — and other times seemed shorter — than the sequences that did not contain oddballs, and this depended on the type of information processing people were engaged in. When people were engaged in direct temporal processing, the sequences that contained oddballs seemed shorter than the sequences that did not contain oddballs. But the opposite was true when people were engaged in indirect temporal processing — the sequences that contained oddballs seemed longer than the sequences that did not contain oddballs" (Simchy-Gross and Margulis 2018 p286). This fits with the dual-process contingency model (table 1.5). The coding efficiency hypothesis would predict that familiar oddball sequences would seen longer, which was not found.

- The resource allocation model (Zakay 1989) (or later called the dual-process contingency model; Zakay 1993) sees subjective duration as based on the amount of attention allocated to time. This occurs as "subjective temporal units, or pulses, created by a pacemaker pass through a cognitive gate and accumulate in a cognitive counter... The more attentional resources allocated to the passage of time during an interval, the wider the gate opens, the more pulses are counted, and the longer subjective duration should become" (Simchy-Gross and Margulis 2018 pp278-279).

- "According to the dual-process contingency model, when people are engaged in direct temporal processing (focusing on time-related aspects of the environment), sequences that contain oddballs should seem shorter than sequences that do not contain oddballs. This is because when people are engaged in direct temporal processing, oddballs should serve to distract attention from counting seconds..., increase information processing load, and decrease the number of subjective temporal units registered in the temporal processor (on which duration is directly based). Conversely, when people are engaged in indirect temporal, or non-temporal, processing (focusing on the inherent time-unrelated aspects of stimuli), sequences that contain oddballs should seem longer than sequences that do not contain oddballs. This is because when people are engaged in indirect temporal processing, oddballs should serve to focus attention on the inherent non-temporal properties of the oddballs themselves, increase the number of changes perceived, and increase the amount of non-temporal information remembered (from which duration is indirectly measured)" (Simchy-Gross and Margulis 2018 p279).

Table 1.5 - The dual-process contingency model.

1.4. Miscellaneous

Binofski and Block (1996) reported the case of a sixty-six year-old man ("B.W"), who as a result of injury to the left superior prefrontal cortex, experienced "external events as seeming to occur at a much faster rate than before the lesion" (p485) [5]. The world was described by him as an "accelerated motion" like a time-lapse film.

When asked to say when one minute had passed, however, his subjective duration was closer to five minutes. "This is consistent with the notion that subjective duration had decreased relative to objective duration" (Binofski and Block 1996 p485).

One explanation for the findings was that "the pacemaker component of his internal clock was now producing pulses at a considerably decreased rate" (Binofski and Block 1996 p491).

Cunningham et al (2001) showed experimentally the ability to adapt to delayed visual feedback by 235 ms. Ten volunteers had to move a small aeroplane on a

[5] The accelerated time experience - Zeitraffer.

computer screen through a series of obstacles. There was a delay between the mouse movement and on the screen. Initially, the participants did poorly and collided into the obstacles. After practice, they showed an improvement in successfully avoiding the obstacles. The control group, who had no delayed feedback, showed a small decline in performance with practice.

When the time delay was later removed from the experimental group, participants experienced "the plane to be moving before they consciously steered it with the mouse" (Fox 2009 p36).

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2. PERCEPTUAL CONSCIOUSNESS

2.1. ISSUES

The problem of "perceptual consciousness" is "the question of how our subjective experiences (colours as we see them; sounds as we hear them; tastes etc as we feel them) could be accounted for in terms of brain processes" (Fazekas and Overgaard 2018 p1) (ie: the neural correlates of consciousness"; NCC). This is the difference between the phenomenal (subjective) and functional (physiological) aspects of consciousness. "Consequently, functional descriptions of proclaimed neural bases of consciousness can always be seen as descriptions of the mere information processing and representational capacities of certain brain states, while it can be denied that the brain states in question correspond to consciousness in any way" (Fazekas and Overgaard 2018 p1).

Overgaard and Fazekas (2016) put it simply: the problem of "how one can measure subjective experiences that are directly available only to the person having them" (p241).

The upshot in methodological terms is correlational studies between subjective experience and the neural basis of consciousness, which seek to "find the constituents (as opposed to the causal background conditions or causal consequences) of the total neural basis of a conscious state (eg: the experience of a particular stimulus) — that is, the totality of those neural states that are jointly sufficient for being in the conscious state in question" (Fazekas and Overgaard 2018 p1). Such studies also seek "the core neural basis of a conscious state, ie: that part of the total neural basis that is responsible for being in the particular conscious state under scrutiny (as opposed to being in another conscious state with different phenomenal character or content)" (Fazekas and Overgaard 2018 p1).

The subjective experience of consciousness depends on verbal reports about it, but such reports require cognitive processes which show up on physiological measures, meaning that "pure phenomenal consciousness" seems impossible to study scientifically.

There is a theoretical debate as to whether "the operation of cognitive access mechanisms is a constitutive condition of being in a conscious state" (Fazekas and Overgaard 2018 p2). Some theories build cognitive access into their definition of consciousness (eg: "global workspace"; Dehaene and Naccache 2001), others do not (eg: "no-report paradigm"; Tsuchiya et al 2015; appendix 2A).

Fazekas and Overgaard (2018) outlined some key areas of discussion:

- The relationship between perceptual consciousness and cognitive access, including alternative approaches.

- Whether conscious perception is rich or sparse - "If the content of perceptual consciousness is richer than the content that can be cognitively accessed, then consciousness overflows access and thus access cannot be necessary for consciousness" (Fazekas and Overgaard 2018 p2).

- Methodological issues, including what is cognitive access.

2.2. PHYSIOLOGY

The claustrum is a thin area of the brain below the neocortex (underneath the temples and just above the ears) with one on each side (thus the plural claustra). These areas are highly interconnected to other cortical regions leading to a description of a "neural Grand Central Station" (Koch 2014).

Crick and Koch (2005) argued that the claustra are "pivotal for consciousness". Koubeissi et al (2014) were able to electrically stimulate these areas in a woman undergoing brain surgery, and consciousness was impaired (ie: stared blankly ahead and became unresponsive to commands). "As soon as the stimulation stopped, consciousness returned, without the patient recalling any events during the period when she was out. Note that she did not become unconscious in the usual sense, because she could still continue to carry out simple behaviours for a few seconds if these were initiated before the stimulation started - behaviours such as making repetitive tongue or hand movements or repeating a word" (Koch 2014 p26).

Fleming et al (2010) linked grey matter volume in the right anterior prefrontal cortex to introspective ability (eg: rating confidence in accuracy of judgment).

2.3. PAIN

In 2008, a US surgeon was conferred a patent for the use of functional magnetic resonance imaging (fMRI) to capture an image of the neuron activity in the brain during chronic pain compared to a pain-free situation (Camporesi et al 2011). In other words, an objective measure of pain.

The ability to make objective measures of subjective experience is termed "neuro-realism" (Racine et al 2005). Camporesi et al (2011) criticised this idea because of the "varying degrees of analysis and interpretation" involved in neuroimaging.

They commented: "Neuroimaging techniques such as fMRI are not the first ones claiming to be an effective 'pain-ometer', but only the most recent. Since the 1960s, 'objective' pain detection techniques based on thermography, that use infrared radiation to measure body surface temperature, have been used. However, the technique has a high rate of false positives, and has never been part of mainstream medical practice" (Camporesi et al 2011 pp271-272).

The subjective experience of pain is influenced by many factors, like expectations, and the baseline of pain varies between individuals. So, in reality, there is unlikely to be an "in pain" brain state that is the same for all individuals than can be compared to a "pain-free" one.

2.4. READING MINDS

When individuals look at visual stimuli, areas of the brain are active, both in terms of visual perception (eg: colour, form) and meaning (eg: semantic representation of information). Many studies have placed individuals in scanners while looking at pictures or films. Is it possible to "reverse engineer" - ie: to tell what an individual is looking at from the pattern of brain activity?

Matsuo et al (2018) reported work with artificial intelligence to link the fMRI scan with a sentence that represents a picture (eg: "a man is surfing on the ocean on his surfboard").

Revell (2018) offered a note of caution: "Because fMRI do not record everything the brain is doing, just a snapshot, this means there may be a limit to the amount of detail that can be extracted using this method" (p14).

The design of "mood state decoders" (ie: neuroimaging techniques) faces the challenges that "neural circuits underlying mood representation do not reside in a single brain region, but rather involve multiple, distributed cortico-limbic regions", and that "tracking mood state variations over time is difficult given the complex nature of mood" (Sani et al 2018 p954).

However, attempts have been made to produce "functional representations of mood in the human brain", including changes in areas of the brain in response to emotional stimuli, or variations in minute electrical activity (Sani et al 2018).

Sani et al (2018) recorded intra-cranial electrocorticogram (ECoG) signals and correlated them with self-reported moods. Electrodes were surgically implanted in seven individuals with treatment-resistance epilepsy in the USA to measure local electrical activity in relation to seizures. Data were collected continuously for several days from many sites in the limbic and cortical areas of the brain. Decoders (algorithms) looked for patterns that could predict mood.

Self-reported mood states related only to depression and anxiety as based on 24 questions (eg: "rate how you feel now: depressed" on scale -3 to +3).

2.5. SYNAESTHESIA

Galton (1883) coined the term "synaesthesia" [6] to describe how "a sensory stimulus presented through one modality spontaneously evoked a sensation in an unrelated modality" (Ramachandran et al 2012 p352) (eg: the number 5 is perceived as "red"). Up to 4% of the general population may experience this phenomenon (Simner et al 2006).

The common types are experiencing letters and numbers with colours (grapheme-colour synaesthesia), and sequences (eg: week days) as having spatial 3D form (spatial-sequence synaesthesia) (Eagleman 2010).

In terms of the neural basis of synaesthesia, the early sensory cross-activation theory is the main explanation. Neurons in areas of the brain usually separate are cross-activated because of increased connectivity (Ramachandran et al 2012). Ramachandran and Hubbard (2001) drew a parallel with the "remapping" of brain areas after a limb amputation.

Ramachandran and Hubbard (2001) tested two synaesthetes who "'saw' a specific colour every time they saw a specific number of letter". For example, one of

[6] Technically, first mentioned in Galton (1880).

them perceived 3s and 7s as red, and 8s and 0s as green.
However, the numbers were not perceived as colours if presented at the periphery of the visual field, nor if Roman numerals were the stimuli.

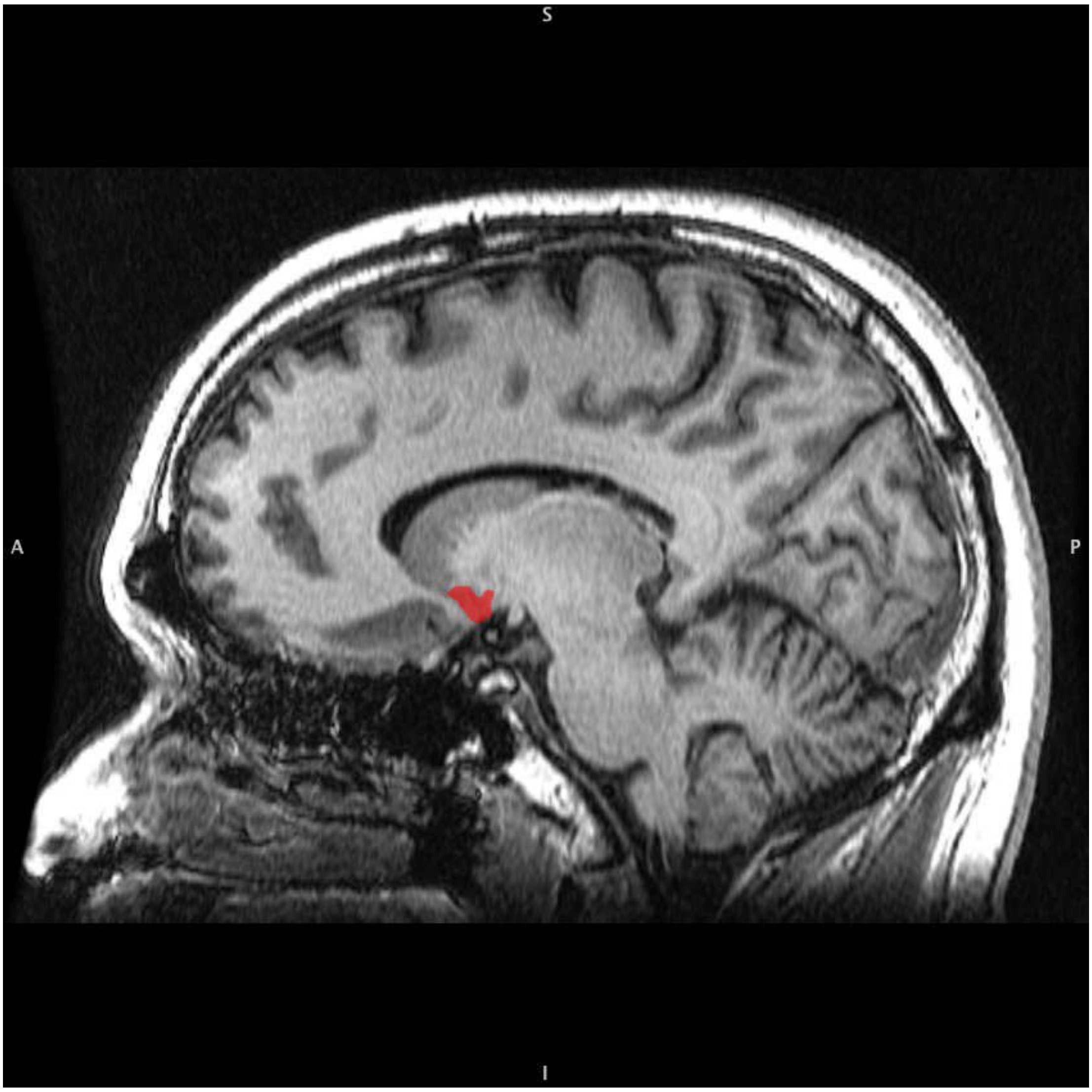
Ramachandran et al (2012) reported a rate case study of "face-colour" synaesthesia, which is manifest as seeing coloured halos or auras around faces. "TK" was a 23 year-old man diagnosed with Asperger's syndrome. The researchers proposed that the "halos originate from cross-activation between area V4 and the fusiform face area, which has been implicated in the processing of an individual's identity... paired with networks involved with facial recognition" (Ramachandran et al 2012 p356).

Watching another human being touched activates brain areas in the observer that are active in the individual being touched. This is the basis to empathy (Banissy and Ward 2007).
Individuals with "mirror-touch synaesthesia" actually experience the tactile sensation on their own body as they observe another person being touched. Banissy and Ward (2007) tested ten individuals with this condition, where the participants were touched on the face or hand while watching another person being touched on the face or hand. In the incongruent experimental condition, where the participant was touched on the hand, say, but saw a touch on the face, more errors were made by the synaesthetes than by twenty controls, as well as a reaction time being slower.

2.6. BRAIN IMPLANTS

Deep brain stimulation (DBS) involves electrodes implanted into an area of the brain which are activated by a battery-powered source placed in the neck, say, similar to a heart pacemaker. DBS is used to control tremors in Parkinson's Disease (PD), for example.

Okun et al (2004) reported smiling and euphoria induced by DBS in a case of a woman with obsessive-compulsive disorder who had electrodes placed in two sides of her brain. DBS in the region of the nucleus accumbens (figure 2.1) led to the patient experiencing "giddiness, feeling happy and feelings of wanting to laugh as well as feeling embarrassed and self-conscious that she was smiling" (Okun et al 2004 p273). The researchers were unsure about the exact brain mechanisms involved in the "stimulation-induced smile", but they "hypothesise the existence of a limbic-motor network responsible for such changes" (Okun et al 2004 p271).



(Source: Geoff B Hall; in public domain)

Figure 2.1 - Magnetic resonance imaging (MRI) scan of the side view of the head showing position of nucleus accumbens.

Prezelj et al (2019) reported a case of an interference with the DBS when a women's apartment was struck by lightning. The electrical devices (eg: television) in the apartment were burned or destroyed, and the DBS power was turned off. "Proximity to high levels of electromagnetic interference may cause DBS system damage, unexpected changes in neurostimulator function, and even serious injury to the patient" (Prezelj et al 2019 p764).

In relation to DBS and PD, Muller and Christen (2011) stated that "a richer provision of patient risk information, counselling of the patient, and more appropriate patient selection criteria based on physical, cognitive, and emotional characteristics will lead to more ethically sound decisions regarding which patients undergo the treatment" (Samuel and Brosnan 2011 p20).

Samuel and Brosnan (2011) criticised this view as placing too much emphasis on individual autonomy. This played down the disruption of social relationships from PD and DBS, and also how the decision to undergo DBS is "embedded within a complex set of relations and policies that constrain (or, ideally, promote) an individual's ability to exercise autonomy with respect to any particular choice" (Sherwin 1998 quoted in Samuel and Brosnan 2011).

2.7. ANAESTHESIA AND AWARENESS

There are two issues related to consciousness and general anaesthesia:

a) Awareness of the external environment - "Intra-operative awareness with explicit recall" has been reported in up to 1% of individuals in studies/clinical settings (Radek et al 2018).

b) Dreaming - Reported by up to half of patients interviewed after recovery from general anaesthesia (Radek et al 2018). "However, the length and depth of anaesthesia, the patient's clinical condition, and the combination of anaesthetics and other medications can affect the presence and later recall of experiences" (Radek et al 2018 p261).

In terms of experimental studies, Noreika et al (2011) used two drugs (dexmedetomidine and propofol) to induce unresponsiveness, and on spontaneous emergence about a quarter of participants reported dream-like imagery, and over one-third suggested some awareness during the process. Radek et al (2018) warned that "dreaming occurs after termination of drug administration before awakening when patients are sedated or in a physiological sleep state" (p261).

Radek et al (2018) attempted to rectify this problem in their experiment with forty-seven healthy young males. The participants were given either dexmedetomidine or propofol to induce unresponsiveness [7]. During this time, sound stimuli were played to test awareness of the external environment. Interviews about dreaming were undertaken at three stages of return to responsiveness.

Dreaming was reported by over three-quarters of participants, but awareness of the sound stimuli was

[7] The levels of anaesthetic were lower than used in surgery (Hooper 2018).

rare.

Jamie Sleigh drew out two points - "conscious is not really a binary phenomenon", and the effects of anaesthesia should be seen as loss of selfhood rather than loss of consciousness (Hooper 2018).

2.7.1. Awareness and Brain States

Brain state	Awake	Aware
Coma	No	No
Vegetative state	Yes	No
Minimally conscious state	Yes	Yes, but severely limited responsiveness

(Source: Schrock 2007 p44)

Table 2.1 - Levels of awareness.

2.8. IMPLICIT PROCESSING

"Blindsight" (Weiskrantz et al 1974) is where individuals report being blind due to damage to the primary visual cortex area of the brain (with no damage to the eyes), but correctly guess the position of an object in forced-choice tests. Blindsight is "an example of 'implicit processing' - residual functioning in the absence of explicit knowledge" (Weiskrantz 1996).

There is also "deaf hearing" (Cowey and Stoerig 1991). Garde and Cowey (2000) reported the case of a patient with deafness caused by damage in certain areas of the brain, who denied hearing sounds, but responded reflexively to them. For example, in the auditory detection test (ie: to say whether a sound (eg: car horn, ambulance siren) was played or not when a light came on), the patient scored the same as healthy controls (12 out of 12, where chance would predict 50% accuracy).

"Affective blindsight" refers to the "uncanny ability" of individuals with cortical blindness to "respond correctly, or above chance level, to emotionally salient visual stimuli presented to their blind fields" (Celeghin et al 2015 p414). de Gelder et al (1999) first reported the phenomenon by a patient called "GY".

"The finding was welcomed by healthy scepticism ..., consistent with the notion that encoding face stimuli is too complex for the visual system deprived of its primary visual cortex" (Celeghin et al 2015 p415).

The basic method of testing involves presenting a facial expression to the blind field and asking the individual to choose from one of two emotions offered. Critics (eg: Cowey 2004) pointed out that "the same stimuli projected to the blind field of GY were also previously shown to his seeing field. Because facial expressions of basic emotions are characterised by distinctive and easily detectable visual features (eg: eyes wide open in fear, or lifted-up lips corners in happiness), correct responses to unseen stimuli may be based on the association and implicit detection of such unique features when the stimuli are first shown to the intact field" (Celeghin et al 2015 p416). But individuals with bilateral damage to the visual cortex (ie: clinically blind in the whole visual field) are still able to successfully guess the facial expression (Celeghin et al 2015).

2.9. APPENDIX 2A - NO-REPORTS PARADIGM

This includes "perceptual readouts" like eye movements and pupil dilation, full inattention studies (ie: where individuals have no conscious awareness of stimuli), and binocular rivalry. This involves presenting two different colour patterns, say, one to each eye.

Tsuchiya et al (2015) stated that the no-report paradigm overcomes the problem of situations where reports are difficult to obtain, which includes babies, animals, and sleeping individuals. As well as conscious but forgotten experiences, those below conscious awareness, and not reportable (eg: minimally conscious state). It has been argued that "phenomenally conscious states overflow cognitive access" as in individuals not noticing objects changing in pictures presented at fast speed (ie: change detection experiments) (Tsuchiya et al 2015).

Scholte et al (2006), for example, found similar EEG recordings when a checkerboard pattern was presented whether the individual consciously noticed the pattern or not.

Overgaard and Fazekas (2016) challenged the validity of "perceptual readouts" as they are "known to reflect pre-conscious events, like, for example, retinal image stabilisation" (p241). Also they stated: "Refraining from issuing a verbal (or other) report obviously does not rule out that participants in experiments are still introspecting, reflecting, associating, and so on" (Overgaard and Fazekas 2016 p241).

A halfway house could be explicit instructions to improve introspective awareness or a combination of report and no-report methods (Overgaard and Fazekas 2016). Tsuchiya et al (2016) argued for the latter including no-report control conditions in experiments.

Also Tsuchiya et al (2016) argued that "while we do not believe that one type of autonomous measure by itself will provide a reliable perceptual readout for all stimulus and task configurations, it may be possible to combine multiple physiological measures to develop more reliable methods that match with phenomenology under specific stimulus conditions" (p242).

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3. A NEW NEUROPHYSIOLOGICAL THEORY OF EMOTIONS

The ability to recognise the pattern of brain activity related to a specific emotion (ie: the neurophysiological basis) is being investigated. in non-human animals, specific brain circuits have been distinguished for behaviours like aggression, and the pursuit of reward (Wager et al 2015). "However, emotional experiences in humans are substantially more complex. Emotions such as fear emerge in response to complex situations that include basic sensory elements such as threat cues as well as mental attributions about context information (eg: the belief that one is being socially evaluated and one's own internal states. A specific emotion category, like fear, can involve a range of behaviours, including freezing, flight, aggression, as well as complex social interactions" (Wager et al 2015 p2).

The many brain studies of human emotions show that the same areas (eg: amygdala) are active during many emotions. "Thus, activation of these regions is not specific to one emotion category or even emotion more generally" (Wager et al 2015 p2).

Wager et al (2015) believed that the key or basic emotions (fear, anger, disgust, sadness and happiness) would show "core" brain activation (ie: particular areas of the brain) and co-activation patterns (ie: particular patterns of activity). The researchers performed a meta-analysis of 148 neuroimaging studies of emotion [8].

The found the following patterns:

i) Cortical patterns - three key findings:

- "there are few differences among emotion categories in the overall level of cortical engagement" (p8).

- "no emotion category mapped to any single cortical network, but emotional categories could be distinguished by significant differences in their profiles across networks" (p8).

- "the grouping of emotion categories in terms of cortical activity profiles did not match folk conceptions of emotions or the dimensions identified in behavioural emotion research. For example, happiness and disgust categories (one 'positive' and one 'negative' emotion) produced very similar profiles, but disgust and fear categories (both high-arousal negative

[8] Neuroimaging studies of emotions have grown in popularity in recent years (appendix 3A).

emotions) produced very different profiles" (p8).

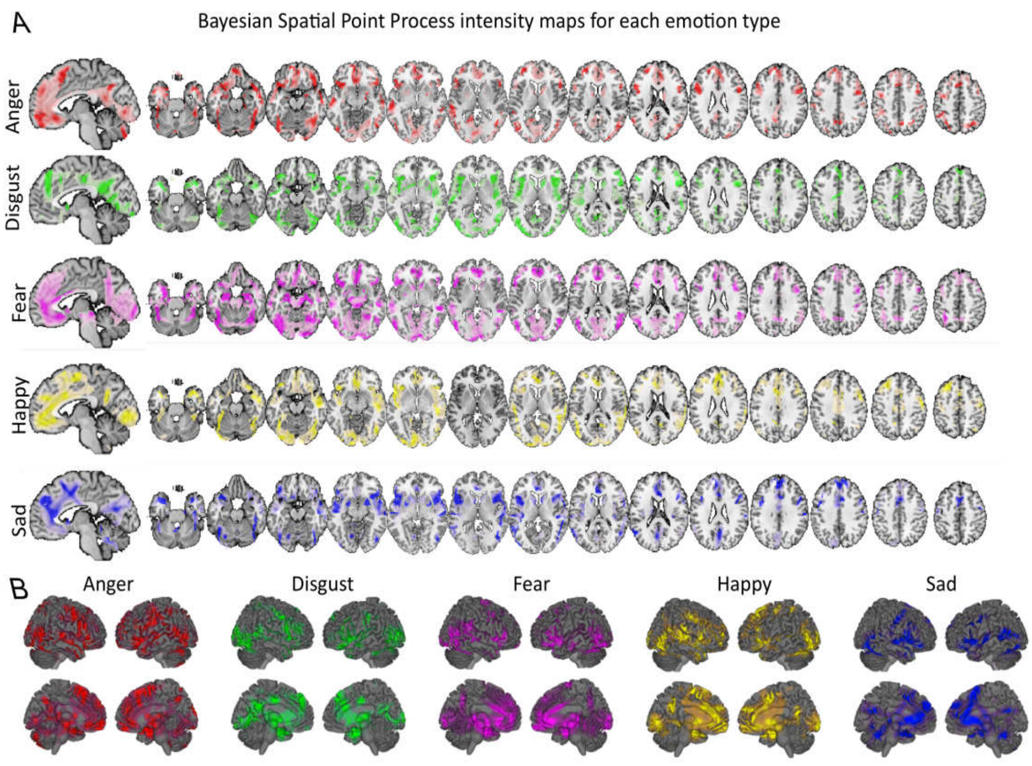
ii) Sub-cortical patterns - three key findings:

- "the largest differences were not overall intensity differences across emotion categories, but rather the profile of differences across sub-regions" (p8).

- Hippocampus and brainstem activity patterns discriminated fear from anger.

- The relationship between cortical, basal ganglia, and cerebellar networks varied among emotions.

Altogether, Wager et al (2015) found that "emotion categories are associated with distinct patterns of activity and co-activation distributed across the brain" (p10) (figure 3.1). The accuracy at predicting the emotion from the brain pattern varied between studies included in the meta-analysis (from 43 to 86%).



(Source: Wager et al 2015 figure S2)

Figure 3.1 - Activity in brain for different emotions.

Traditional theories of emotions have argued for distinct populations of neurons in the brain for the basic emotions (mostly in the sub-cortical areas, like the amygdala), and these are similar in all animals (eg: Tracy and Randles 2011).

Wager et al's (2015) findings challenged this idea. They stated: "The areas of the brain sufficient to represent and classify emotion category in our results are not architecturally separate, and include cortical networks that may not have any direct homologue in nonhuman primates. Our results suggest these cortical networks act as a bridge between sub-cortical systems in different ways, depending on the emotion category..." (p12).

The implication is a new way of grouping emotions for Wager et al (2015):

- Anger and fear are very similar in cortical patterns and activity, and "preferentially engage cortical processes that support an 'external orientation/object focused' schema, characterised by goal drive responses where objects and events in the world are in the foreground" (p13).

- Happiness, sadness and disgust have similar networks of activity. These emotions "engage cortical patterns that support an internal orientation/homeostatic focused schema, characterised by orientation to immediate somatic or visceral experience, which prioritises processing of interoceptive and homeostatic events" (p13).

This study also challenged the idea of an "emotion brain" (or "limbic system") (Maclean 1952) separate from systems of memory, perception and attention, for example. Wager et al (2015) were clear: "Our results provide a compelling and specific refutation of that view. Single regions are not sufficient for characterising emotions: Amygdala responsivity is not sufficient for characterising fear; the insula in not sufficient for characterising disgust; and the sub-genual cingulate is not sufficient for characterising sadness" (p14).

Table 3.1 summarises the patterns of cortical and sub-cortical activity for each emotion.

The key limitation of this meta-analysis was the use of other studies, which varied in neuroimaging and general methodology (eg: how emotions were defined and studied).

Speculative Interpretation, psychological predictions/ inferences	Similarity	Coactivation patterns	Activity patterns	
Strong goal-driven attention component, with central cerebellar involvement for strong sensorimotor integration; lower 'impulsive' general motor priming than often assumed; anger studied in scanner is more calculated than impulsive	Cortical, amygdala pattern similar to fear; hippocampal and cerebellar pattern unique	Strong visual-to-frontoparietal cortex; strong cortico-cerebellar and cortico-amygdalar, mainly fronto-parietal and dorsal attention networks; strong subcortical coactivation	Strong dorsal attention, fronto-parietal cortico-cerebellar circuit; default-mode cortical activity; Relatively little basal ganglia	**Anger**
Strong cortical involvement, emphasizing ventral attention and somatosensory networks implicated in exogenously driven attention; Strong cortico-striatal coactivation may prioritize immediate action generation: low cerebellar involvement suggests less fine-grained control of responses	Cortical pattern similar to happiness and sadness, but stronger engagement; subcortical pattern in basal ganglia relatively unique	Strong somatomotor cortex to basal ganglia; low cerebellar and strong intracortical coactivation; visual-to-frontal cortex network coactivation is critical bridge integrating subcortical systems	Ventral attention network in cortex; dorsal attention in basal ganglia	**Disgust**
Fear as studied in scanner has strong visual-to-subcortical component; reduced demand on cortically driven planned responses/ goal. Amygdala activity/co-activation strong, but dominated by basalateral complex implicated in cue-threat associative learning.	Cortical, amygdala pattern similar to anger; distinctive, bilateral hippocampal pattern	Weak cortical-subcortical coactivation except visual cortex, and weak intracortical coactivation, strong basal ganglia coactivation with amygdala and thalamus	Strong amygdala (basolateral) hippocampus; parietal and somatosensory thalamus; visual, default-mode, and limbic basal ganglia	**Fear**
Relatively low demand for integrated planning/action systems (somatosensory/cerebellar); Particularly strong limbic network implicated in positive value and endogenously driven expectancies; Low amygdala involvement consistent with reduced reliance on exogenous cues.	Cortical pattern similar to sadness and disgust; distinctive left-sided hippocampal pattern	Strong within-system coactivation (cortex, basal ganglia, thalamus, cerebellum), but relatively weak cortical-subcortical coactivation	Low amygdala, thalamus, and basal ganglia activity; Left-sided hippocampus and medial temporal	**Happy**
Very weak activation of integrated planning/action systems (dorsal attention/cerebellar), and systems driven by exogenous cues (visual, amygdala); very weak cerebellar integration and system integration overall; reflexive cerebellar-brainstem responses strong and operate without co-activation with cortex	Cortical patterns similar to happiness and disgust; pattern in cerebellum and brainstem more similar to fear	Very weak intra-cortical and cortical-subcortical coactivation relatively isolated systems; strong cerebellar-brainstem coactivation, but weak cerebellar coactivation with other systems	Low amygdala, hippocampal, thalamic activity; Limbic, frontoparietal, and default basal ganglia networks; Limbic cerebellum	**Sad**

doi:10.1371/journal.pcbi.1004066.t002

(Source: Wager et al 2015 table 2)

Table 3.1 - Summary of brain activity associated with five basic emotions.

APPENDIX 3A - MISOPHONIA

Misophonia is "an affective sound-processing disorder characterised by the experience of strong negative emotions (anger and anxiety) in response to everyday sounds, such as those generated by other people eating, drinking, chewing, and breathing" (Kumar et al 2017 p527).

Kumar et al (2017) reported "greatly exaggerated" responses in certain areas of the brains of sufferers, specifically "in the anterior insular cortex (AIC), a core hub of the 'salience network' that is critical for perception of interoceptive signals and emotion processing" (p527). There was also increased connectivity between the AIC and other areas of the brain, found in this study with 22 misophonic individuals and 22 age- and sex-matched controls, who listened to three sets of sounds - misophonia triggers (eg: chewing), general unpleasant (eg: a scream), and neutral (eg: rain) - while in a brain scanner.

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4. FOOLING OURSELVES IN OUR DECISIONS

4.1. CHOICE BLINDNESS

"Choice blindness" (Johansson et al 2005) is a version of "change blindness" [9] (appendix 4A).

Researchers showed participants pictures of pairs of female faces, and asked them to choose the more attractive. After an initial choice, the participants were asked if they were sure, and the researchers reported, "unknown to the participants, on certain trials, we used a card magic trick to covertly exchange one face for the other" (Hall et al 2010 p54). The change was only noticed in one-quarter of trials.

Hall et al (2010) investigated this phenomenon further with consumer choices. One hundred and eighty individuals at a supermarket in Sweden were asked to taste pairs of jam (eg: ginger vs lime) or tea (eg: apple pie vs honey). In each case, participants made an initial choice, the pair was switched in positive secretly, and the participants chose again. Around one-third of the changes were detected. "Thus, in the great majority of trials they were blind to the mismatch between the intended and the actual outcome of their choice, and instead believed that the taste or smell they experienced in their final sample corresponded to their initial choice" (Hall et al 2010 p58).

4.2. PROBLEM-SOLVING PROBLEMS

In situations of unsolved problems, there is a common theme in anecdotes of famous cases: "A flash of

[9] This is where individuals will not notice obvious change in the environment if the changes are not important (ie: not attended to). Simons and Levin (1998) set up field experiments where a stranger would change appearance halfway through a conversation. The aim was to see if the participants noticed. For example, at a reception desk, the attendant reaches behind a door and another person takes their place. It may seem obvious that we will notice it is a different person, but half the participants did not.

insight pops unexpectedly into the mind of the individual after he or she has put an unsolved problem aside for a period of time, having failed in initial attempts to solve it. This temporary shift away from an unsolved problem that allows a solution to emerge seemingly as if from no additional effort is termed an incubation period (Wallas 1926)" (Sio and Ormerod 2009 p94). What is the evidence for incubation enhancing problem-solving?

Sio and Ormerod (2009) found 117 relevant studies on incubation and problem-solving for their meta-analysis, of which eighty-five reported positive effects (ie: a period of incubation improved problem-solving compared to no period). Overall, an incubation period does improve problem-solving success in some situations.

Wallas (1926) originally proposed four stages to problem-solving - preparation, incubation, illumination, and verification. In terms of more recent theories, Sio and Ormerod (2009) distinguished conscious and unconscious ones to explain the role of incubation. The conscious-work hypothesis suggested that incubation (ie: no conscious thinking about the problem) allows for mental fatigue to be overcome, for example, while "the unconscious-work hypothesis suggests that positive incubation effects are the result of gradual and unconscious problem-solving processes that occur during an incubation period" (Sio and Ormerod 2009 p95).

Sio and Ormerod (2009) considered the potential variables that influenced the success of incubation, including:

- The interpolated task (ie: what is being done during the incubation period) - high or low cognitive demand tasks. High cognitive demand tasks reduced the effectiveness of incubation.

- Length of the incubation period - longer is generally better.

- Nature of the problem - "Individuals solving creative problems were more likely to benefit from an incubation period than individuals solving linguistic and visual problems" (Sio and Ormerod 2009 p107).

- Length of the preparation period - a longer period is important.

Sio and Ormerod (2009) summarised their findings: "the meta-analysis results support the existence of incubation effects, though there appears to be a range of effects specific to particular tasks and performance conditions. When attempting to solve creative problems that require a wide search of knowledge, individuals benefit from an incubation period. Problems that involve reaching some kind of insight into a unique solution do not always benefit from incubation under all conditions. In the case of linguistic problems..., there is a modest incubation effect but only where the incubation period is filled with a low cognitive demand task" (p109).

A familiar idea can prevent a creative alternative ("design fixation"; Chrysikou and Weisberg 2005), or one solution to a problem can block other possibilities ("einstellung effect"; Luchins 1942).

Thomas and Didierjean (2016) investigated whether "a single exposure to an unfamiliar and unlikely false solution could prevent participants from finding a more obvious and contextually different one, even if participants are invited to search for an alternative solution" (p170). Ninety students at a French university saw a magic trick in one of three conditions. In the original trick condition, participants saw a brown-backed card and six red-backed cards all face down. The participant chooses a red-backed card, which is turned over and it is the same as the brown-backed card when turned over. The participant is then asked how the trick is done. The answer is that all cards are the same, which 83% of participants got.

In the false solution conditional trick condition, the participants were told beforehand that the magician can influence their choice of red-backed card. Only 17% of participants gave the correct solution to the trick afterwards. The false solution extinction trick condition was the same, but after the trick, the participants were told that the magician had not influenced them, and they were explicitly asked to find another solution. Only 13% of participants gave the correct solution (figure 4.1).

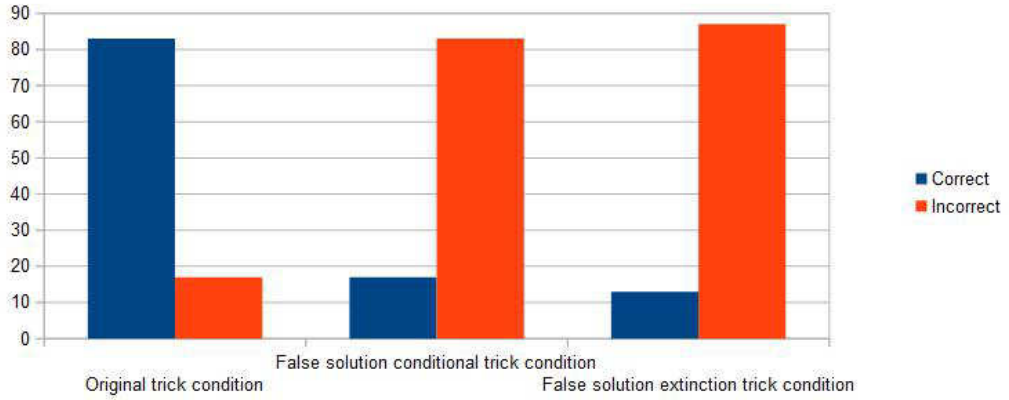

Figure 3.1 - Answers to question (%), "what is the secret of the trick?".

Thomas and Didierjean (2016) offered this explanation for the findings: "when the human mind is confronted with an insight problem, it may be more efficient to focus attention on a given and potentially correct solution (even if it is an unlikely and unfamiliar one) than to spend time and attention on finding a hypothetical alternative one" (p172).

4.3. BODY ILLUSIONS

Researchers can create "body illusions" to explore the feelings related to body ownership. For example, with the "rubber hand illusion" (Botvinik and Cohen 1998), individuals can come to perceive a rubber hand as part of their body if it is visibly stroked while the actual hand is invisibly stroked [10]. "The illusory self-attribution of the rubber hand is dependent on the integration of temporally and spatially congruent visual, tactile, and proprioceptive signals in multi-sensory cortical areas in the pre-motor, intra-parietal, and cerebellar cortices" (Guterstam et al 2015 p1).

Petkova and Ehrsson (2008) (appendix 4B) produced the "full-body illusion", where "the participants view a mannequin's body being touched through a set of head-mounted displays (HMDs) while they receive correlated tactile stimulation on their real body" (Guterstam et al 2015 p1).

Guterstam et al (2013) showed the "invisible hand illusion" with the same procedure as the "rubber hand illusion". The real hand is stroked out of sight while the stroking action is performed to "a hand-shaped volume of empty space in front of the participant. This setup resulted in the referral of tactile sensations to the empty space and the perception of having an invisible hand, which was associated with increased neural activity in the multi-sensory regions that were found to be active during the rubber hand illusion" (Guterstam et al 2015 p1).

Guterstam et al (2015) created the "invisible body illusion" by touching an empty representing the invisible body as the individual's body was touched.

4.4. CLASSICAL CONDITIONING WITHOUT AWARENESS

The human brain can process sensory stimuli outside of conscious awareness (ie: subliminal perception or non-

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[10] One participant said: "I found myself looking at the dummy hand thinking it was actually my own" (Botvinick and Cohen 1998).

conscious awareness). Studies have shown that "non-conscious stimuli have a pervasive effect on human brain function and behaviour and may affect learning of complex cognitive processes such as psychologically mediated pain responses" (Jensen et al 2015 p7863).

In their experiment, Jensen et al (2015) divided 49 health volunteers into four conditions related to pain perception and classical conditioning. During the conditioning phase, participants received heat stimuli to their forearm, which they rated for pain level. At the same time, faces were shown on a screen (either at a speed to consciously perceive or subliminally), in order to create the association between a face and a level of pain. During the test phase, heat stimuli were used while the face were shown again.

The four conditions were:

a) Faces presented subliminally during conditioning and testing.

b) Faces presented at a conscious perception speed, but subliminally during testing.

c) The opposite to condition (b).

d) Conscious perception in both conditioning and testing phases.

If the faces have become associated with a high or low temperature, then participants will rate the hot stimuli during testing as hotter or colder based on the faces presented. Normal classical conditioning would expect this finding in condition (d), which was the case.

Classical conditioning with non-conscious awareness was also found as participants rated the test stimuli as hotter or colder in conditions (a-c) based on the associated faces shown. In other words, a hot stimulus was perceived as hotter when paired with associated "hot faces" than associated "cold faces" (whether the classical conditioning had involved conscious or subliminal perception).

4.5. MISCELLANEOUS ILLUSIONS

The size-weight (or Charpentier-Koseleff) illusion is where two objects of the same weight but of different sizes will be perceived as of different weight. Visually, a larger object will be perceived as heavier than a smaller object. In picking up the two objects, an individual will report that the heavier object feels lighter than the smaller one.

"What does the effect occur? When you reach out for the bigger object, you expect it to weigh more (given the assumption that it is made of the same stuff) and you exert greater lifting force. Because it weighs the same as the smaller object (which you expected to weigh less), however, you actually experience it as being lighter, relative to the smaller object" (Ramachandran and Rogers-Ramachandran 2008 p19).

But the illusion does not apply with a solid disc and a ring of the same size and weight (Hubbard and Ramachandran 2004).

Research has found a relationship between the size of the V1 visual cortex area of the brain and the strength of perceptual illusions, such that the smaller the area the stronger the illusion. "Curiously, the size of the two immediately adjacent visual areas did not influence the amplitude of the illusion" (Koch 2011 p16).

A forward-moving wheel can appear to be rotating backwards (known as the "continuous wagon-wheel illusion"; c-WWI) (VanRullen et al 2008). The right inferior parietal lobe [11] is involved because disruption of this area with low-frequency repetitive transcranial magnetic stimulation for ten minutes weakened the illusion. VanRullen et al (2008) used four volunteers at a US university medical centre.

4.5.1. Taste Perception

Adolphs et al (2005) described the case of "B", a 72 year-old man who after a severe Herpes simplex encephalitis had extensive brain damage. His impairments included short-term and long-term memory problems (eg: memory span of 40 seconds), and, the focus here, a profound impairment in taste and smell perception.

"B" was offered two solutions to drink - one contained high levels of salt (saline) (aversive taste) and the other of sugar (sucrose) (pleasant taste). He consumed fully both drinks with a pleased facial expression on the nineteen times given. Five healthy controls distinguished between the drinks, and refused the saline one after one sip.

When "B" was asked to say which solution he preferred, on eighteen of nineteen trials the sucrose solution was chosen, but he could not explain why. Adolphs et al (2005) said that "B" showed that "stimuli can be discriminated without being consciously perceived and can be preferred without being remembered" (p860).

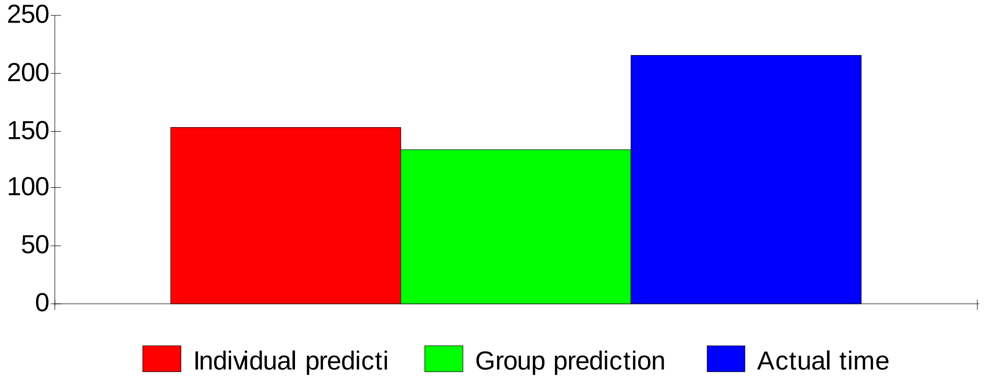
[11] "The right parietal lobe is involved in attending to visual events that are displaced in space and time. In particular, patients with lesions of the right inferior parietal cortex, and suffering from left visual neglect, have difficulties in perceiving long-range apparent motion, or in judging the temporal direction (onset vs offset) of luminance transients" (VanRullen et al 2008 p1).

The researchers continued: "Of what is B aware when he chooses sucrose over saline? When asked about his preferences, he was unable to give any additional information, other than stating that he liked the chosen solution better. We believe that he is aware of his preference of sucrose over saline, without awareness of the identity of either. That is, the taste comparison likely provides B with an overt feeling that he would rather drink one solution than another, without any overt knowledge of the taste experiences that would normally provide the justification for this preference" (Adolphs et al 2005 p861).

4.6. OPTIMISTIC BIAS

"Task completion forecast" is the prediction as to when a task will be finished. Individuals often predict finishing sooner than they actually do, and this is called the "planning fallacy" (Kahneman and Tversky 1979), which is a form of "optimistic bias" (where "people make highly favourable estimates of the time it will take to complete an upcoming task, even though they are fully aware that similar tasks have taken longer in the past"; Buchler et al 2005 p48). Individuals not involved in a task (neutral observers) are less prone to the planning fallacy than those involved (actors) (Buchler et al 2005).

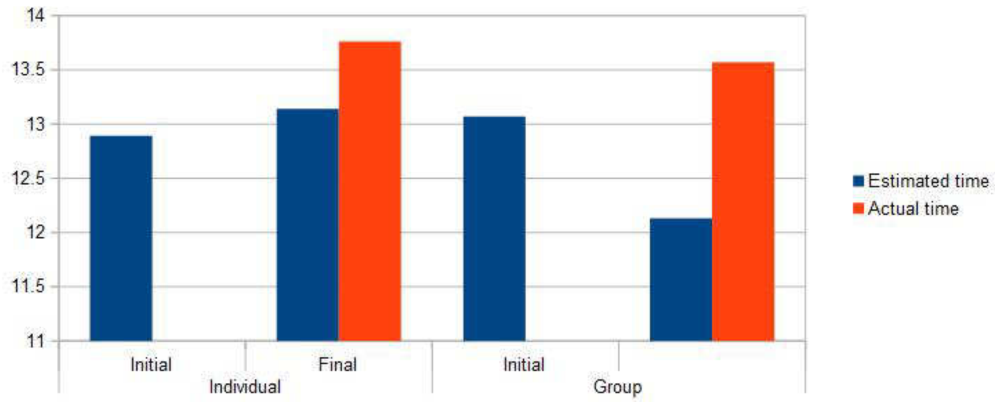
Buchler et al (2005) showed the planning fallacy by both individuals and groups. In Study 1, business studies students at a Canadian university were asked to individually predict how long a small group project (ie: course assignment) would take to complete, and then to make a group prediction. The actual completion time was significantly longer than both types of prediction (figure 4.2).



(Data based on Buchler et al 2005 table 1 p51)

Figure 4.2 - Means in Study 1 (days).

Study 2 imposed more control on the research with a laboratory experiment. Groups of three undergraduates were given a 100-piece jigsaw to complete as quickly as possible. It had been calculated a pilot study that the average completion time was over fourteen minutes. Prior to starting, participants were asked to predict the completion time either individually or after group discussion. These were the initial predictions, and then after reflection or discussion, final predictions. The average initial predictions were less than thirteen minutes individually, and over thirteen minutes as a group (which was significantly less than the actual time taken). But the estimates changed by the final prediction - individuals predicted longer and groups less time (figure 4.3).



(Data based on Buchler et al 2005 tables 2 and 3 p54)

Figure 4.3 - Means in Study 2 (minutes).

Study 3 was a replication of Study 2, but involving a group task outside the laboratory (eg: finding answers to factual questions). The same results were found.

In summary, Buchler et al (2005) said: "Across three studies, we found a consistent optimistic bias in time predictions for collaborative group projects, we found that predictions based on group discussion were more optimistic than individual predictions..." (p59).

4.7. APPENDIX 4A - CHANGE BLINDNESS AND DRIVING

Galpin et al (2009) examined change blindness in a driving-based experiment. Fourteen drivers and fifteen non-drivers, who were undergraduates at a UK university, were presented with pictures of a crossroads from a driver's vantage point. An image was presented for 1000 ms, then the same image with one crucial change for the same amount of time, and the participants had to spot the change from a choice of four options. The changes were varied in their relevance to driving (eg: traffic sign (relevant) or shop window (irrelevant)), and the location in the picture of the change (central or peripheral).

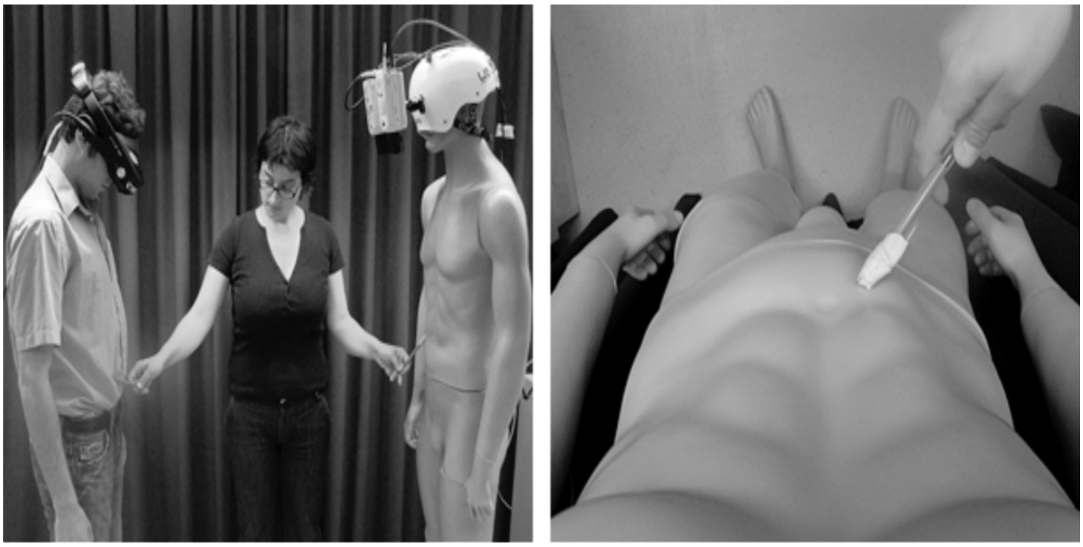
The participants were better (faster) at detecting relevant changes than irrelevant ones, both centrally and peripherally. There was no difference between drivers and non-drivers. Overall, it was felt that "the images were activating a driving-related schema that was guiding attention to relevant scene details" (Galpin et al 2009 p183). But, put another way, individuals showed change blindness for irrelevant stimuli even in the central position of the image.

4.8. APPENDIX 4B - PETKOVA AND EHRSSON (2008)

Petkova and Ehrsson (2008) performed five experiments.

Experiment 1 - Thirty-two young adults in Sweden were presented with the illusion of owning a mannequin's body. Petkova and Ehrsson (2008) described how the illusion was created: "Two CCTV cameras were positioned on a male mannequin such that each recorded events from the position corresponding to one of the mannequin's eyes. A set of head mounted displays (HMD) connected to the cameras was worn by the participants, and connected in such a way that the images from the left and right video cameras were presented on the left and right eye displays, respectively, providing a true stereoscopic image. Participants were asked to tilt their heads downwards as if looking down at their bodies. Thus, the participants saw the mannequin's body where they expected to see their own" (p2) (figure 4.4). The participant's body was stroked out of view in the same place as on the mannequin's body in view for two minutes (synchronous condition). The control group (asynchronous condition) experienced asynchronous touch (eg: different places on the body between the participant and the mannequin). The participants reported feeling the mannequin's body to be their own body.

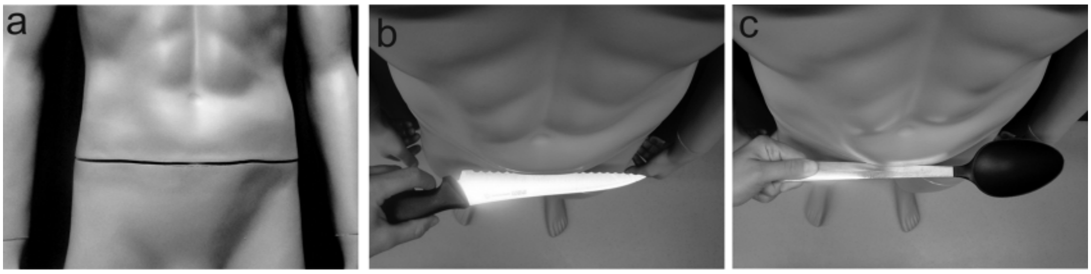
Experiment 2 - This experiment measured the physiological response to a threat to the mannequin's body using ten new participants. After creating the body illusion as above, the experimenters either cut the mannequin's body with a knife (synchronous or asynchronous to feeling the knife on their body) or touched the mannequin with a spoon (control condition (figure 4.5). The participants showed an emotional response to the knife as "one would anticipate a person



(Source: Petkova and Ehrsson 2008 figure 1)

Figure 4.4 - Photographs of experimental set-up for body swap illusion.

to respond were their own body being threatened" (Petkova and Ehrsson 2008 p3). The response was strongest (ie: significantly different to the other two conditions) for the synchronous knife condition.



(Source: Petkova and Ehrsson 2008 figure 9)

Figure 4.5 - Photographs of experimental set-up for knife threat.

Experiment 3 - This experiment with thirteen new participants was similar to the previous one but include the knife threat to the hand (synchronous and asynchronous) as well. Participants showed an emotional response "after synchronous visuo-tactile stimulation of either the hands or the abdomen as compared to the asynchronous control conditions" (Petkova and Ehrsson 2008 p3).

Experiment 4 - Twelve participants were recruited for this experiment. The knife threat condition was compared to a mannequin or to a rectangular object of the same size. The participants only showed an emotional response with the mannequin. "Thus, people can only experience human-like bodies as part of themselves" (Petkova and Ehrsson 2008 p4).

Experiment 5 - Twenty adults participated in this experiment to create a body swap illusion. "In this experiment, the experimenter was wearing a specially designed helmet equipped with two CCTV cameras mounted in such a way that they presented the viewpoint of the experimenter. In turn, the participants stood directly opposite the experimenter, wearing the HMDs, which were connected to the CCTV cameras on the experimenter's head. Thus, the participants were facing the cameras. The participants were asked to stretch out their right arm and take hold of the experimenter's right hand, as if to shake it" (Petkova and Ehrsson 2008 p4) (figure 4.6).

Participants reported comments like "Your arm felt like it was my arm, and I was behind it", "I felt that my real/own body was someone else" or "I was shaking hands with myself!" (Petkova and Ehrsson 2008 p5), and they responded emotionally to the knife threat to the experimenter's arm as if their own arm.

(Source: Petkova and Ehrsson 2008 figure 6)

Figure 4.6 - Photograph of set-up in Experiment 5.

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5. MEMORY TOPICS

5.1. SURVEY OF AUTOBIOGRAPHICAL MEMORY

Palombo et al (2013) noted that the "real-life expression of memory involves multiple capacities interacting with sensory, perceptual, attentional, and motor abilities" (p1527), and laboratory memory tests struggle to capture these aspects, particularly in the case of autobiographical memory (AM). In fact, testing and neuroimaging find differences between naturalistic and laboratory memory tasks (Palombo et al 2013).

Palombo et al (2013) developed the Survey of Autobiographical Memory (SAM) to measure differences in the ability to recall such memories. AM includes an episodic part (eg: personal events) and a semantic part (eg: knowledge about the self). Palombo et al (2013) also included prospection or future thinking (ie: imagining future events in one's life), and remote system memory (which is "awareness of previously encoded spatial co-ordinates that enable orientation and navigation in previously encountered settings"; Palombo et al 2013 p1527).

Palombo et al (2013) collected 102 questionnaire items from the literature and other measures, which covered episodic AM (eg: "When I remember events, in general I can recall people, what they looked like, or what they were wearing"), semantic AM (eg: "I can learn and repeat facts easily, even if i don't remember where I learned them"), spatial memory (eg: In general, my ability to navigate is better than most of my family/friends"), and future thinking (eg: When I imagine an event in the future, the event generates vivid mental images that are specific in time and place").

Six hundred and ninety-one volunteers in North America rated each item on a five-point scale. Participants also completed other memory questionnaires and a recognition memory test.

The final SAM had 26 items, and a brief version (B-SAM) ten items (table 5.1). The underlying factor was "good versus poor episodic autobiographical, semantic, and spatial memory. In other words, when people reported having high or low abilities for one category of memory, they tended to do the same for other categories" (Palombo et al 2013 p1534).

The SAM does not assess the accuracy of AM, but it measures an individual's perception of their AM. However, there was a significant positive correlation between the recognition test and the SAM items, which suggested that self-reported perceptions of AM may indicate accuracy of recall.

- Specific events are difficult for me to recall (episodic AM item).
- I am very good at remembering information about people that I know (eg: the names of co-worker's children, their personalities, places friends have visited etc) (semantic AM item).
- I get lost easily, even in familiar areas (spatial memory item).
- When I imagine an event in the future, I can picture images (eg: people. objects etc) (future thinking item).

Each item scored 1 (strongly disagree) to 5 (strongly agree).

(Source: Palombo et al 2013 appendix)

Table 5.1 - Examples of item from SAM and B-SAM.

An uncommon phenomenon is "highly superior autobiographical memory" (HSAM), where individuals are able to recall in detail the days of their lives and public events that happened on those days (McGaugh and LePort 2014). This ability is not learned or trained (as in memory competitors), nor like an audio and video recordings, and other aspects of memory are average (eg: recall of visual objects) (McGaugh and LePort 2014).

There are some brain differences between HSAM individuals and controls (eg: in white matter, so greater efficiency in transferring information between brain regions) (LePort et al 2012).

5.2. HIPPOCAMPUS CHANGE

Conscious recollection (or long-term declarative memory) involves the hippocampus, and the adjacent brain areas like the prefrontal cortex (PFC) (Hannula and Ranganath 2009).

Hannula and Ranganath (2009) got eighteen participants to view face-scene pictures for 2000 ms each (ie: learning phase), and later showed them the scene (as a cue) before a choice of three faces (recall phase). "Results showed that activity in the hippocampus during presentation of the scene cue predicted subsequent viewing of the associated face during the three-face test display, even when participants failed to explicitly identify the match. In contrast, activity in PFC regions was sensitive to subsequent response accuracy but did not predict viewing of matching faces on incorrect trials. Finally, functional connectivity between lateral PFC and hippocampus was increased during presentation of the three-face test display on correct as compared to incorrect trials. Together, these results suggest that hippocampal activity may support the expression of relational memory and that recruitment of a broader network of regions may be required to use this information to guide overt behaviour" (Hannula and Ranganath 2009 p596).

To establish causation (rather than association) requires a study over time that shows the before and after a particular event or intervention. Woollet and Maguire (2011) used the case of London licensed taxi drivers having "the Knowledge". "In order to qualify as a licensed London taxi driver, a trainee must learn the complex and irregular layout of London's ~25,000 streets within a 6-mile radius of Charing Cross train station, along with the locations of thousands of places of interest" (Woollet and Maguire 2011 p2108). This can take 3-4 years to pass the examinations (called "appearances").

Cross-sectional comparisons between qualified London taxi drivers and non-taxi-driving matched controls have found more grey matter volume in the former's posterior hippocampi (figure 5.1) and less in the anterior hippocampi in brain scans (eg: Maguire et al 2000) (appendix 5A). Other studies have found a positive correlation between hippocampal volume and years of London taxi-driving experience (eg: Woollett et al 2009).

(Source: User: Washington Irving; in public domain)

Figure 5.1 - Position of hippocampi in the brain looking from below.

Studies of the brain (usually of rats) have found particular cells involved in navigation generally (Moser and Moser 2016):

i) "Place cells" - Different cells fired in the hippocampus when a rat was placed in different locations in an enclosure.

ii) "Grid cells" - Cells in the entorhinal cortex fired when a rat moved over a particular place in an enclosure. These cells provide information about distance and deviation.

iii) "Head-direction cells" - Cells that fired when a rat faced a particular direction.

iv) "Border cells" - These fire when a rat approached a wall or edge of an enclosure.

v) "Speed cells" - Respond to animal's running speed.

Together these cells are involved in the "cognitive map" (Moser and Moser 2016).

Woollet and Maguire (2011) performed a longitudinal study with 79 male trainee London taxi drivers from the start of training until qualification, and compared them to 31 male controls. All participants underwent structural magnetic resonance imaging scans prior to training (time 1), and 3-4 years later (time 2).

The taxi drivers who completed "the Knowledge" (n = 39) had increased grey matter volume in the posterior hippocampi by the time that they were qualified, which was not observed in trainees who failed to qualify or controls. Woollet and Maguire (2011) commented: "That acquiring 'the Knowledge', which encompasses spatial learning and memory, can drive changes in posterior hippocampus illustrates the close relationship between this region and spatial navigation and suggests that the hippocampus acts as a storage site for the spatial information acquired during 'the Knowledge', or as a processing hub for detailed navigational information" (p2111).

They continued: "we have shown that there is a capacity for memory improvement and concomitant structural changes to occur in the human brain well into adulthood" (Woollet and Maguire 2011 p2112).

The hippocampus has the job of "pattern separation" (ie: recording the details of an event to allow future distinction of one event from another), and "pattern completion" (recollection of an event when cued). The latter takes place in the region of the hippocampus called the CA3, and pattern separation in the dentate gyrus (Kheirbek and Hen 2014).

Kheirbek et al (2012) reported that inhibiting pattern separation stopped learning and created generalised anxiety. Rats learned that being placed in a particular coloured box led to a mild electric shock, say, but another colour did not. Animals that could not produce new neurons in the dentate gyrus remained afraid of both colours. Rats with enhanced growth of neurons learned to distinguish the colours quicker (Kheirbek and Hen 2014).

5.3. IMPROVING WORKING MEMORY

The "ability to temporarily hold information in mind and work with it" (ie: working memory; WM) can be impaired in many ways (eg: acquired head injuries, cancer treated with radiation, schizophrenia) (Spencer-Smith and Klingberg 2015).

Training programmes are available to improve WM, particularly using computer technology. Research has shown that such programmes can improve WM on similar non-trained tasks (ie: near transfer effects) (Spencer-Smith and Klingberg 2015). For example, Melby-Lervag and Hulme's (2013) meta-analysis found larger benefits for verbal WM than visuo-spatial WM. Thus, "'working memory training' is not a unitary concept" (Spencer-Smith and Klingberg 2015 p2).

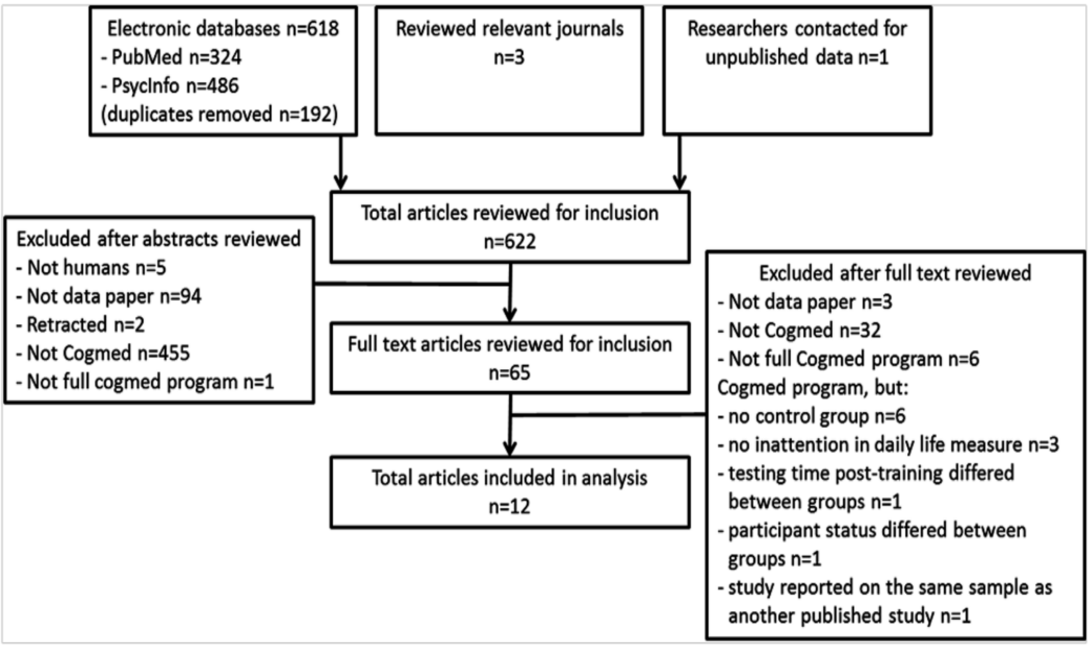
"Far transfer effects" are WM abilities that are quite different to the training programme (eg: reasoning, reading comprehension). One of these effects is inattention in daily activities, which Spencer-Smith and Klingberg's (2015) meta-analysis found improved after the "Cogmed" WM training programme.

Twelve relevant studies were included in the meta-analysis (figure 5.2). The "Cogmed" programme involves computerised training of WM in around twenty sessions with rewards for completion. Verbal and visuo-spatial WM are trained differently depending on the age of the user. Only studies with passive controls (eg: no treatment) were included.

As with any meta-analysis, the studies varied in methodology, which included:

- Measurement of inattention in daily activities (eg: behaviour rating scales; observation of off-task behaviour when performing a goal-directed task).

- Raters of inattention blind to condition or not (eg: parents; teachers).



(Source: Spencer-Smith and Klingberg 2015 figure 1)

Figure 5.2 - Flow diagram of search and selection procedure for relevant articles.

- WM performance (eg: listening recall; digits backwards).

- Length of follow-up (eg: 2 - 8 months post-training).

- Participant characteristics (eg: age).

- Type of control group (eg: waiting list; ordinary computer game).

Working memory declines with age, it is thought, because of a disconnection between the prefrontal and temporal regions of the brain (Devlin 2019). Reinhardt and Nguyen (2019) showed temporary improvements in working memory in older adults using non-invasive electrical brain stimulation. Forty-two 60-76 year-olds received 25 minutes of stimulation, and, for the following fifty minutes, their working memory showed improvements to mirror the performance of 20 year-olds on the tests.

5.3.1. "Doorway Effect"

The "location updating effect" describes how "people remember less about objects that they recently interacted with, particularly if they are currently carrying them, if they walk through a doorway compared to if they simply walk across a large room" (Pettijohn and Radvansky 2018 p430). Put in everyday language, walking through doorways causes forgetting (as first shown experimentally by Radvansky and Copeland 2006) [12].

The "event horizon model" of event cognition (Radvansky 2012) explains this phenomenon. Crossing an event boundary as in a doorway means "the event model for the prior location is removed from active working memory, and a new event model of the new location is created" (Pettijohn and Radvansky 2018 p430).

This effect is studied mostly in virtual environments. For example, Pettijohn and Radvansky (2018) asked participants to navigate between rooms (shift condition) or across a large room (no-shift condition) in a virtual environment using a joystick. In the process, participants picked up a virtual object. After navigation, the screen went blank, and participants were asked to recall the object. Recall was better in the no-shift condition.

5.4. APPENDIX 5A - ADULT NEUROGENESIS

The hippocampus is unique in that new neurons are added throughout life in a process called "adult hippocampal neurogenesis" (AHN) (Moreno-Jimenez et al 2019). This was first shown by Eriksson et al (1998), but there is some debate about it as "the limited availability of adequately preserved human brain tissue samples, together with the heterogeneity of tissue processing methodologies, is considered to have contributed to a lack of consensus in this regard" (Moreno-Jimenez et al 2019 p554).

The process of AHN has been well studied in rodents (Moreno-Jimenez et al 2019). Using post-mortem human brain samples of fifty-eight individuals in Spain, Moreno-Jimenez et al (2019) found evidence of new brain cells in the hippocampus "up to the ninth decade of life". There was also evidence of AHN being inhibited in Alzheimer's disease cases.

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[12] Also called informally the "doorway effect".

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6. PERCEPTION TOPICS

6.1. VISUAL PERCEPTION

"The world that you see is not the world that exists - it has been heavily retouched by your retina" (Masland 2017 p418). This process involves different types of cells in the retina (five main types and more than sixty sub-types in vertebrates; Masland 2017). For example, retinal ganglion cells respond to changes in light, but not stable illumination (Masland 2017).

In the brain's visual cortex are atypical pyramidal neurons (APNs) which are connected by dendrite spines to many other neurons. When a sufficient number of neurons fire, the APN is triggered. Neurons respond to specific attributes of the visual stimuli, like orientation, known as the receptive field (Rose and Hubener 2017).

Iacaruso et al (2017) mapped the activity of neurons in the mouse brain to show that the neurons connect to the APNs in an organised way. The researchers summed up: "Inputs representing similar visual features from the same location in visual space are more likely to cluster on neighbouring spines" (Iacaruso et al 2017 p449). The electrical activity of individual neurons (ie: firing) was measured in response to small black-and-white squares presented in different locations of the mouse's field of view.

Shen et al (2015) showed that visual working memory stored information in the process of visual perception. Participants were shown the elements of an illusion in sequence for 1000 ms each. The whole illusion would only be perceived if each element was kept in visual working memory and "assembled" there. The participants did not necessarily consciously register the whole illusion, but perceived one line as longer than another when both of equal length as in the Ponzo illusion.

Auditory-visual multi-sensory interactions improve visual perception. Romel et al (2009) focused on looming (or approaching) sounds (ie: sounds that gradually increase in amplitude). Participants were played looming, receding or stationary sounds while brain activity in the visual cortex was measured. Looming sounds produced more activity (ie: enhanced visual perception).

In terms of an evolutionary explanation, an approaching sounds could signal danger, so it is important to be able to see what it is quickly.

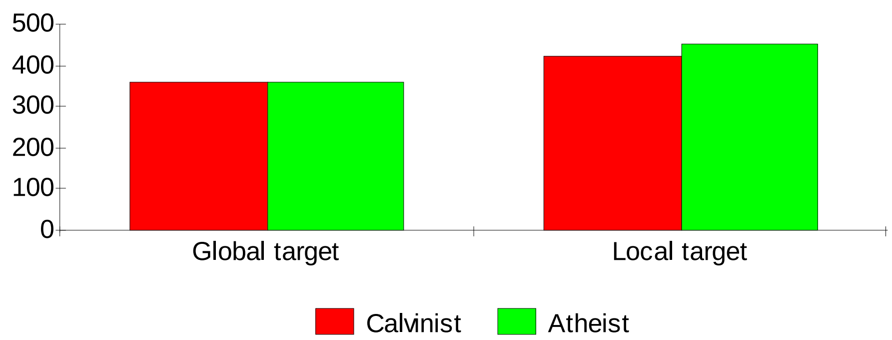
6.2. PERCEPTUAL BIAS

The "New Look" approach (Erdelyi 1974) to visual perception proposed that perception and attention are influenced by moods, needs, expectations, beliefs, and culture (Colzato et al 2008).

Colzato et al (2008) added religion in a study with forty young adults in the Netherlands who were either self-identified Calvinists or atheists. Participants performed the Local-Global Task (Navon 1977), where a large letter (global) is made of smaller letters (local) (figure 6.1). Individuals are told to respond as quickly as possible to a particular letter. Those who respond faster when the target letter is the large one are better at global processing, while faster at the smaller letter is local processing (appendix 6A).

Figure 6.1 - Examples of stimuli like those used in the Local-Global Task.

Colzato et al (2008) found that overall the global targets were perceived faster than the local targets, but the Calvinist participants were faster for the local targets (figure 6.2).



(Data from Colzato et al 2008 table 1)

Figure 6.2 - Mean reaction times (milliseconds).

The participants in the study were matched for sex, age, intelligence, and socio-economic status, but the data were only correlational.

The researchers proposed this explanation: "According to our approach, social experience and procedures (in our case religion), and the selective reward they provide, can induce the emphasis on and higher weighting of socially relevant perceptual features and characteristics of processed events. We speculate that exercising a religion and being exposed to particular religious practices may lead, among other things, to a chronic bias towards particular attentional control parameters. The sphere sovereignty principle underlying Dutch neo-Calvinism has led to a rigorous 'pillarisation' (segregation) of Dutch society and established the idea that, in a nutshell, everyone should 'mind his or her own business' – which among other things inspired a rather liberal policy regarding drug use, abortion, or euthanasia. Calvinists may have learned since early age to focus on local rather than global dimensions, at least as compared to people not sharing their religious practices. In general, we suggest that peoples' attentional processing style reflects possible biases rewarded by their religious belief" (Colzato et al 2008 p2).

In terms of further research, Colzato et al (2010), in their first experiment, recruited four groups of Dutch adults - conservative and liberal Calvinists, atheists, and "baptised atheists" (former Calvinists). Calvinists (including former members) responded faster to the global targets than the local ones.

In the second experiment, the researchers compared eighteen Italian Roman Catholics and eighteen Seculars, and eighteen Israeli Orthodox Jews and 18 Seculars. Roman Catholics responded faster to global targets than Italian Seculars, and Orthodox Jews faster than Israeli Seculars.

Finding objects in a "cluttered and continually changing visual environment" requires the ability to "ignore salient-but-irrelevant objects to attend to less salient visual-search targets in a timely fashion" (Gaspar and McDonald 2014 p5658). In other words, to avoid being distracted.

Gaspar and McDonald (2014) found evidence from their target searching experiments [13] for the salient-signal suppression hypothesis (ie: "observers suppress signals arising from salient-but-irrelevant items when searching

[13] Participants had to find a particular coloured circle among ten circles of the same size, and the reaction time was measured.

for a known target"; p5658) [14]. The process works like this: "(1) salient visual items compete for control (that is, they generate competing 'attend to me' signals) during a stage of visual processing that precedes selection and (2) the visual system decides whether to select the location of the most salient item for further processing (selection for identification) or to selectively suppress that location to avoid further processing of the item there" (Gaspar and McDonald 2014 p5664).

6.3. BRUNER AND GOODMAN (1947)

Bruner and Goodman (1947) outlined the views of the time that "perception has been treated as though the perceiver were a passive recording instrument of rather complex design" (p33). Their research challenged this idea by showing perception varies depending on "behavioural factors". Prior research had shown that perception is influenced by reward and punishment, and by practise.

Bruner and Goodman (1947) proposed that perception will vary depending on the social value of an object. Their experiment involved thirty 10 year-olds who were divided into two groups. The experimental group involved 20 of them who were asked to estimate the size of different US coins from memory. This was done with a circle of light on a screen which could be adjusted by the child to the size of a particular coin. In an experimental variation the coins were actually present when the estimates of the circle of light were made.

The control group (n = 10) viewed cardboard discs of identical size to the coins. The two independent variables were the value of the coins, and the presence or absence of the coin when adjusting the circle of light, and the dependent variable was the discrepancy in judgment of the size of the circle of light from the identically sized cardboard discs.

It was found that the experimental group estimated the size of more valuable coins as larger - ie: "the greater value of the coins, the greater is the deviation of apparent size from actual size" (Bruner and Goodman 1947 p38). For example, the 1 cent coin was perceived as 15% larger than its actual size, while for the 25 cent coin the overestimation was 35%. The perception of the size of the cardboard discs by the control group were accurate.

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[14] The alternative is the dimensional weighting hypothesis where "salience signals associated with the local contrast of visual stimuli are adjusted pre-attentively depending on the currently relevant visual feature dimension" (Gaspar and McDonald 2014 p5658) (ie: salience information is "boosted" to make it "stand out").

In further analysis, the experimental group was divided into "rich" (ten children from "well-to-do" families in Boston) and "poor" (ten children from "Boston's slum area"). It was found that the "poor group overestimates the size of coins considerably more than does the rich" (Bruner and Goodman 1947 p39) (table 6.1).

Coin	Rich group	Poor group
1 cent	10	>20
25 cents	20	>50

(Based on data in Bruner and Goodman 1947 figure 2 p40)

Table 6.1 - Mean overestimation (%) of the size of two coins compared to actual size.

When estimating the size of the circle of light with the coins present, the rich group differed only slightly in their estimates compared to the coins absent, whereas the poor group had a large discrepancy (table 6.2). This was taken as strong evidence that perception is influenced by the value of an object.

Coin	Rich group	Poor group
Absent	>25	35
Present	20	50

(Based on data in Bruner and Goodman 1947 figure 3 p41 and figure 4 p42

Table 6.2 - Mean overestimation (%) of the size of the 25 cent coin when the actual coin is present or absent.

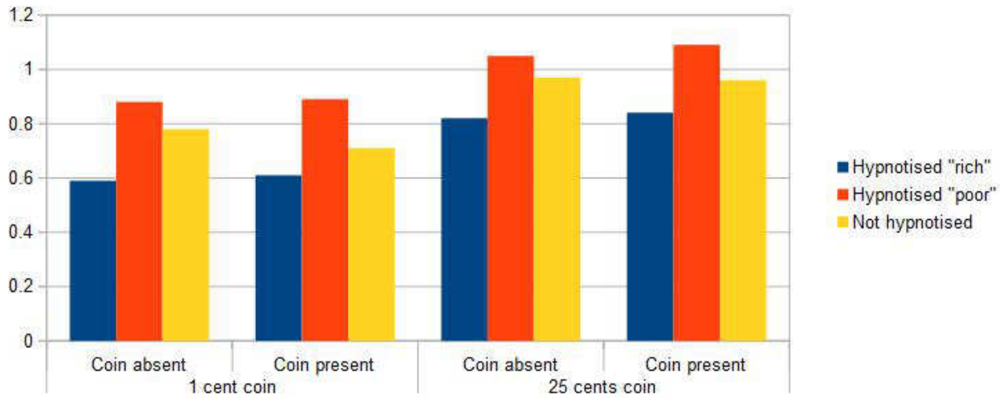
Carter and Schooler (1949) found different results with poor children overestimating the size of the coins compared to rich children from memory, but there was no difference between the groups when the coins were present. This study involved 48 children estimating the size of the circle of light as coins from memory or present, or aluminium or cardboard discs present.

Ashley et al (1951) performed a variation of these studies. Rather than using participants who were rich or poor, the researchers hypnotised US college students to believe that they were rich or poor. "The size of the light spot that the subjects set as equal to the coins differed markedly between the 'rich' and 'poor' states..." (Ashley et al 1951 p568) (figure 6.3).

The researchers also had a variation which involved different metals (lead, silver, white gold, platinum).

During the "poor" state of hypnosis, participants perceived the objects as larger than in the "rich" state.

This study had the advantage that the same participants were hypnotised to believe themselves rich and poor in each case, as well as performing the estimates of size unhypnotised.



(Data from Ashley et al 1951 table 1 p570)

Figure 6.3 - Mean estimates of size of 1 cent and 25 cents coins (where actual size = 1 inch).

6.4. APPENDIX 6A - "S.E"

Aviezer et al (2007) reported the case of "S.E" whoc could not identify the global letters, but still showed interference when recognising the local letters. For example, recognition of small "z" that make up a large "k" (incongruence) was slower than recognition of small "k" in a large "k" (congruence).

"S.E" was a man in his 50s at the time who, after a stroke, could not recognise objects (visual agnosia) and faces (prosopagnosia). Recognition of the global/large letters in the Navon task was less than 50% (ie: chance), but he was 92 ms faster to recognise local/small letters in the congruent condition (compared to the incongruent one).

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7. LANGUAGE TOPICS

7.1. EVOLUTION OF LANGUAGE

Humans are primates, and this order appeared around 65 million years ago (Aboitiz 2018). A key feature of primate species is brain size, and consequently cognitive abilities. But within the order of primates, there is great difference, particularly in relation to language (appendix 7A).

Put simply, the question becomes about why humans speak and other primates, particularly chimpanzees, do not. Aboitiz (2018) observed that "all movements used by humans when speaking can be executed by monkeys, and computer simulations of monkey vocalisations were able to generate human-like speech... [and] monkeys naturally emit sounds similar to human vowels, but they do not organise them into complex phonological sequences" (p4). Direct cognitive control over the muscles in the lips and larynx was an important evolutionary development for humans (Aboitiz 2018).

Also important were brain developments, like the articulatory or phonological loop, which "enhanced working memory capacity, enabling early humans to learn increasingly complex utterances" (Aboitiz 2018 p1).

Aboitiz (2018) summed up the evolution of speech thus: "early human communication was probably multi-modal, using both vocalisations and gestures, as it is today. The vocal learning skills of early humans may have been put to use to mimic the sounds of animals, water, the wind, or other elements nearby, together with gestural pantomime... Likewise, they may have developed learned alarm calls that signal specific predators, that were accompanied by gesticulations... This emerged into a primitive, gestural-vocal proto-semantic system... However, pantomimes and manual gestures probably never went much beyond the stage observed in normally speaking modern humans. On the other hand, the elaboration of auditory-vocal networks and the gradual consolidation of the phonological loop eventually enabled our ancestors to start communicating increasingly complex meanings through the voice... In later stages, the acquisition of semantics and a primitive lexicon may have been essential for the separation between both kinds of expression, and possibly contributed to the lateralisation of these functions, with phonology and speech on the left hemisphere and music/prosody in the right hemisphere, both communicating via the corpus callosum" (pp10-11).

The drivers for this evolution included sociality and co-operation, tool-making and culture, and specific ecological circumstances (Aboitiz 2018).

7.2. COLOUR NAMES

Gibson et al (2017) began: "The question of colour-naming systems has long been caught in the cross-fire between universality and cultural relativism. Cross-cultural studies of colour naming appear to indicate that colour categories are universal. However, the variability in colour category boundaries among languages, and the lack of consensus of the forces that drive purported universal colour categories, promotes the idea that colour categories are not universal, but shaped by culture" (p10785). Alternatively, the colour-usefulness hypothesis (or efficient-communication hypothesis; Regier et al 2015) argued that "differences in colour categorisation between languages are caused by differences in overall usefulness of colour to a culture" (Gibson et al 2017 p10785).

Gibson et al (2017) compared Tsimane people (isolated Amazonian hunter-gatherers), Bolivian-Spanish speakers, and English speakers in colour naming tasks with familiar and unfamiliar objects, and natural and artificially-coloured ones. It was found that "the Tsimane were less likely to use colour terms when describing familiar objects. Colour-naming among Tsimane was boosted when naming artificially coloured objects compared with natural objects, suggesting that industrialisation promotes colour usefulness" (Gibson et al 2017 p10785).

7.3. UNTRANSLATABLE WORDS

Lomas (2016) collected 216 "untranslatable" words to describe feelings, relationships, or character (table 7.1). Untranslatable means that "other languages lack a single word/phrase for the phenomenon" (Lomas 2016), and, in some cases, the "foreign" word is imported into the language - eg: schadenfreude (German) used in English now to mean pleasure at the misfortune of another person.

Feelings	Relationships	Character
• uitwaaien (Dutch) - "to walk in the wind for fun" • me yia (Greek) - "a blessing of good health for others" • fernweh (German) - "call of faraway places" ukiyo (Japanese) - "a sense of living in these moments of fleeting beauty, detached from the pains of life"	• ah-un (Japanese) - unspoken communication with close friends • koi no yokan (Japanese) - "the feeling on meeting someone that falling in love will be inevitable" • naz (Urdu) - "the assurance and pride one can feel in knowing that the other's love is unconditional and unshakable" firgun (Hebrew) - "the act of saying nice things to another simply to make them feel good"	• sisu (Finnish) - "extraordinary determination in the face of adversity" • majime (Japanese) - "someone who is reliable, responsible, and able to get things done without causing problems for others" • ming miu (Chinese) - "die without regret" kombinowac (Polish) - "working out an unusual solution to a complicated problem, and acquiring coveted skills or qualities in the process"

Table 7.1 - Examples of "untranslatable" words.

7.4. ABSTRACT CONCEPTS

The capacity for abstract thought is "one of the hallmarks of human cognition" (Borghi et al 2018), but what is happening in the brain during abstract thought?

One general idea is that, like concrete concepts, "abstract concepts are grounded in the sensori-motor system" (Borghi et al 2018). For example, Brookshire and Casasanto (2018) applied transcranial direct current stimulation (tDCS) to the dorsolateral prefrontal cortex (DLPF), and found that handedness (concrete) and emotional concepts (abstract) were linked (appendix 7B).

Borghi et al (2018) noted three tends in recent research on this topic:

i) Different kinds of abstract concepts with different brain representations - The former "ranging from numbers to emotions and from social roles to mental state concepts" (Borghi et al 2018). Desai et al's (2018) meta-analysis, for example, found that four types of abstract concepts (numerical and emotional concepts, morality judgments, and theory of mind) involved a widespread distribution of brain areas. Each of the concepts was associated with unique areas of brain activity, while common areas were activated in all of them.

ii) Multiple representation views - "According to such approaches abstract concepts are grounded in sensori-motor systems but also involve linguistic, emotional and social experiences as well as internal experiences" (Borghi et al 2018 p3).

iii) Variability in abstract concepts based on language spoken - This is the idea that language shapes the way concepts are understood and used. "Abstract concepts are more detached from sensory experiences, and so could be more affected by linguistic variability than concrete concepts" (Borghi et al 2018 p3).

For example, Majid et al (2018) (appendix 7C) compared Dutch speakers and Jahai speakers (hunter-gatherers in Malaysia) in naming odours. The "Jahai speakers were both more succinct and quicker in naming odours, using abstract concepts (eg: musty) rather than referring to concrete odour sources (eg: smells like lemon). Emotional reactions to odours instead did not differ across the two cultures/languages. The variation of odour terms across cultures suggests that different cultures and languages can differently shape our concepts — and this might happen in particular for concepts that do not refer directly to a concrete, single object, as do odour concepts" (Borghi et al 2018 p6).

7.5. BILINGUALISM

Bilingualism is the ability to speak two languages, usually from learning them both when young. There is some suggestion that such individuals have general cognitive benefits or executive function (EF) advantages compared to single-language speakers (monolingualism) (eg: Bialystoke 2011).

There has been plenty of research on this question, but de Bruin et al (2015) saw a bias in publishing studies that showed bilingual advantage compared to studies with no difference or negative results. These researchers looked at 104 conference abstracts on the subject, and, of the half that were eventually published in journals, over two-thirds found a bilingual advantage.

Most studies compare a group of bilinguals with monolinguals, but there are methodological issues with such a design, including (Paap et al 2015):

- Confounders of bilingualism and cognitive ability - eg: socio-economic status, immigrant status, cultural differences, gender, and education. Paap et al (2016) commented: "For example, bilinguals are more likely to be better educated in Hyderabad, but less educated in Houston. As long as the language(s) one speaks matters in the social dynamics of a population there are likely to be other important factors that covary with bilingualism" (p307).

- How well or often the two languages are used by bilinguals.

- The statistics used to analyse the data.

- The tests used to measure general or specific cognitive functions.

- Problems with replication of findings.

- The operationalisation of the dependent variable - eg: absolute or relative reaction time. Issues of validity of the measures of EF, like inhibitory control (Paap et al 2016).

- Samples (eg: two languages spoken; native bilinguals or second language learners).

- Causality - "Another complication in the study of differences between naturally occurring populations is that significant relationships need not be causal and, even when they are, the direction can be ambiguous. Thus, although the control required to learn a second language could enhance general EF, it is just as likely that individuals with better EF are better able to master a second language" (Paap et al 2016 p307).

- Design - longitudinal vs cross-sectional; prospective vs retrospective.

Concentrating on bilingual advantage in EF in performance of verbal tasks, Paap et al (2015) argued that "either bilingualism does not enhance EF in any circumstance or only in very specific, but undetermined, circumstances" (p266). While Paap et al (2016) suggested "a shift away from the yes-no question of does bilingualism enhance EF" (eg: continuous measures of bilingualism and EF).

7.6. APPENDIX 7A - EVOLUTION ACCEPTANCE

Surveys show that acceptance of evolutionary theory is around half of respondents in the USA (Weisberg et al 2018).

One explanation is linked to political or religious worldviews. "Rather than genuinely probing individuals' considered views, questions about evolution acceptance trigger people's identification with religious or political groups, leading them to respond consistently with their group's values" (Weisberg et al 2018 p212). This is called "identity-protective cognition" (Kunda 1990). The alternative is the "knowledge-deficit hypothesis", which links acceptance of evolutionary theory to knowledge about it.

Weisberg et al (2018) found evidence to support the latter. The researchers asked "YouGov" to conduct an online survey of 1100 Americans. Knowledge of evolution was tested by seventeen multiple-choice items, and acceptance of evolution by a series of statements (eg: "animals and plants developed entirely through natural processes"). Other measures, like general science knowledge were also taken.

Individuals who "failed" the evolution knowledge test (ie: less than 60%) were less likely to accept evolution. Put another way, for each one point increase in knowledge score, respondents were 1.22 times more likely to accept evolutionary theory.

The researchers accepted: "Because this study is correlational, it does not provide definitive evidence about potential causal links among these factors: Greater knowledge of evolution might lead to views that more closely resemble the scientific consensus, but it is also possible that individuals who accept evolutionary theory are more likely to learn about it" (Weisberg et al 2018 p220).

7.7. APPENDIX 7B - BROOKSHIRE AND CASASANTO (2018)

Affective motivation is "the predisposition to approach or avoid physical or social stimuli" (Brookshire and Casasanto 2018 p1). Approach-related emotions, like happiness and anger, are linked to the left fronto-temporal cortex (FTC), while the right side is active in avoidance-related emotions, like disgust and fear (Brookshire and Casasanto 2018).

This hemispheric specialisation is linked to hand movements, according to the "sword and shield hypothesis" (ie: sword (approach) in dominant hand and shield (avoidance) in non-dominant hand) (Brookshire and Casasanto 2012). "People often use their dominant hand for approach actions, and their non-dominant hand for avoidance actions. For instance, people tend to use the dominant hand to grab a small ball (an approach action), but raise the non-dominant hand reflexively to protect themselves if a ball is thrown at them unexpectedly (an avoidance action)" (Brookshire and Casasanto 2018 p1).

Brookshire and Casasanto (2012) measured electrical activity in the FTC, and found that right-hand dominant individuals with high approach-related emotions had higher left FTC activity at rest, but for left-handers it was the right FTC.

Brookshire and Casasanto (2018) applied transcranial direct current stimulation (tDCS) to different areas of the FTC. They summed up the findings: "In strong right-handers, left-excitatory tDCS led to increased approach motivation, whereas right-excitatory tDCS led to decreased approach motivation. In non-right-handers, by contrast, we found the opposite pattern: right-excitatory tDCS increased approach motivation and left-excitatory tDCS decreased it" (Brookshire and Casasanto 2018 p4).

Brookshire and Casasanto (2018) extrapolated that the emotions of approach and avoidance "may re-use neural circuits that evolved primarily for performing motor actions. Affective motivational states may consist in highly abstracted motor plans, which indicate a state of readiness to perform either approach- or avoidance-related actions" (p5).

7.8. APPENDIX 7C - MAJID ET AL (2018)

Majid and Burenhult (2018) gave ten men who spoke Jahai and ten English men common odours familiar to Westerners (eg: petrol). It was found that English speakers used concrete vocabulary to describe the odours (eg: smells like lemon), while Jahai speakers used abstract odour terms (eg: "stinging sorts of smells"). "In addition, English participants had very low agreement in how they described odours, whereas Jahai participants had significantly higher agreement" (Majid et al 2018 p2).

Majid et al (2018) developed this study with a comparison of fifteen male and fifteen female native Jahai speakers and thirty age- and gender-matched Dutch speakers. Thirty-seven individual smells were presented. The participants were asked to describe or name the smell, and their facial expressions were recorded.

Almost all verbal responses of the Jahai speakers were abstract terms, whereas Dutch speakers used more concrete terms. "Despite these differences in language, both groups appeared to have similar initial affective responses to odours – as measured by facial expressions..." (Majid et al 2018 p7).

Majid et al (2018) concluded that "odours may initially be treated in similar ways according to their pleasantness across diverse communities. But the fact that they vary in their linguistic expression across cultures suggests that the notion of what is 'abstract' or 'concrete' is in part a culturally-contingent fact" (p7).

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8. MISCELLANEOUS TOPICS

8.1. NEURONS AND INTELLIGENCE

Attempts have been made to explain the differences in intelligence between individuals in terms of differences in their brains. For example, higher intelligence is associated with faster firing neurons, and thicker grey matter in the temporal and frontal cortices in brain imaging studies (Goriounova et al 2018).

Based a brain tissue study, Goriounova et al (2018) found that higher IQ scores were associated with more complex dendrites (ie: connections between brain cells), and this would account for faster firing of neurons. The brain tissue was obtained from 44 individuals undergoing neurosurgical procedures in the Netherlands. The IQ of these individuals was tested one week prior to surgery.

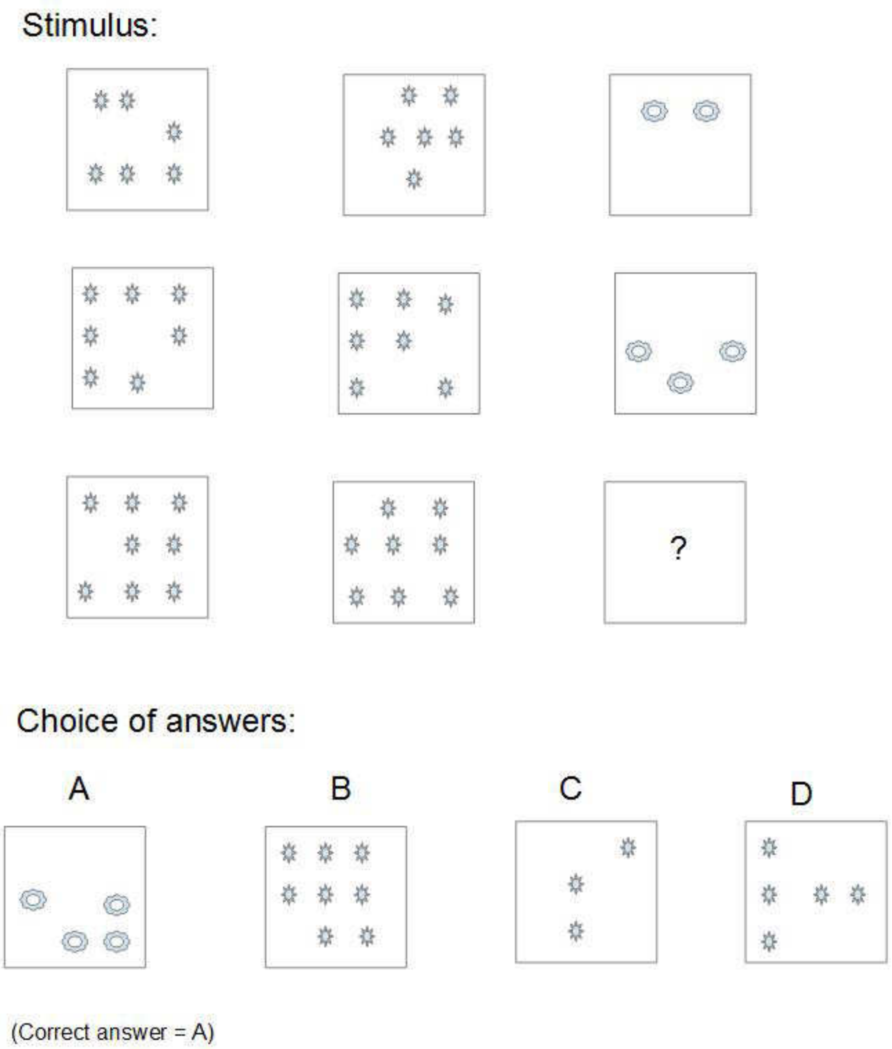
8.1.1. Modelling Intelligence

Abstract reasoning is seen as "a hallmark of human intelligence" (Barrett et al 2018). One common test of it is "Raven's Progressive Matrices" (Raven 1938), which involves spotting an underlying rule in a series of 3 x 3 matrices of shapes, colours, and numbers (figure 8.1).

Barrett et al (2018) produced a neural network model to learn and solve matrices that was "notably proficient at certain forms of generalisation, but notably weak at others" (p1).

8.2. CROSSWORD PUZZLES

Nickerson (2011) summarised the cognitive processes involved in solving crossword puzzles, and, along with others, argued for their use in studying cognition.



(After Barrett et al 2018 figure 1)

Figure 8.1 - Example of Raven's progressive matrices.

1. Clue types.

a) Semantic - These usually required general knowledge which involves semantic memory (or declarative knowledge).

b) Thematic - The target words are linked by a theme that may be explicit (eg: puzzle title) or not. This type of clue and completing words in a puzzle show how information is stored and searched for.

2. Knowledge types.

a) Linguistic knowledge - "semantic knowledge

(knowledge of word meanings, synonyms, antonyms, and word associations), syntactic knowledge (knowledge of parts of speech, tenses, contractions, and word spellings), and statistical knowledge (knowledge of the relative probabilities of specific letters occurring in specific positions within words, and of specific letter combinations)" (Nickerson 2011 p226).

b) General knowledge.

c) Puzzle-specific knowledge - Like a skill, regular puzzlers will develop "short-cuts" to solve particular puzzles - eg: knowledge of words used in crosswords but rarely in everyday life.

3. Lexical search - Searching for the correct word, which includes creativity, and the tip-of-the-tongue phenomenon.

Strategies to solve clues include intuitive (or heuristic) or analytic, of which, what called Nickerson (2011) called "grasping at straws" is "an extreme instance". He explained: "I use clues, including indirect and tentatively inferred clues, in a desperate attempt to find candidates that, if they are in my lexicon at all, are proving to be very difficult to access. Sometimes the desperation is sufficiently great to evoke mechanically stepping through some set of possibilities. Trying every letter in every unfilled position is usually practically feasible only when all but one or two of the letters of a target word have already been discovered; however, sometimes it can be useful to do a letter-by-letter search for a single position, even when several other positions are still blank" (Nickerson 2011 p231).

4. The feeling of knowing or not knowing - Smith and Clark (1993) found "a positive correlation between the feeling of knowing and the time people took before giving up on questions they could not answer; more generally, they found that, when people were able to answer a question, the higher the confidence in the answer, the more quickly it was produced, whereas when they could not produce an answer, the stronger the feeling of knowing, the longer they took before giving up" (Nickerson 2011 p232).

8.3. DECISION-MAKING

In studies of the brain during decision-making, Platt and Glimcher (1999) reported that the size of the reward was important, and different neurons in the parietal cortex were "involved in weighing up the expected pay-off or value of each alternative. The decisions seems to be made on the basis of which bunch of location-tuned cells 'win' by reaching a certain threshold of activity" (Phillips 2008 p35). This experiment involved rhesus macaques looking in a particular direction for a reward of orange juice.

Deaner et al (2005) developed this work further. Macaques learned to choose between two images for a reward of orange juice. But this reward could be "swapped" for the opportunity to look at images of faces or bottoms of other macaques. Males were willing to forego their juice reward to see female bottoms (which is a cue to fertility) and the faces of dominant males (which is important in a social hierarchy), but not subordinate faces (Phillips 2008).

Rudebeck et al (2006) confirmed these results by seeing how long macaques would wait to take food. They were distracted from the food by images of high-status male faces, and female bottoms, and by images of snakes (a predator).

In terms of humans, face-recognition performance, as in an eye-witness identity parade, can be influenced by what the individual was doing immediately prior to the face-recognition test. For example, describing a face beforehand makes face recognition harder, as does describing an unrelated object (Lewis 2006).

The Navron stimuli works in different ways. "If participants read out the large letters of these stimuli, then subsequent face recognition performance was found to be better than controls, but if the participants read out the smaller letters of the same stimuli they did worse than the controls" (Lewis 2006 p1433).

In a real-life situation, individuals are unlikely to encounter a Navron stimuli before an identity parade at a police station. But eye-witnesses do things while waiting. Lewis (2006) tested this experimentally by asking participants to either read a passage of a novel, solve sudoku puzzles, literal or cryptic crosswords. This task was performed by sixty undergraduates in Wales for five minutes after seeing fourteen faces for three seconds each, and before a memory test of the fourteen faces mixed with fourteen new ones. The target faces were slightly different images.

Face recognition accuracy was significantly poorer after the cryptic crossword. Lewis (2006) speculated that "in doing a cryptic crossword, one typically has to suppress the immediately obvious meaning of a word within the clue in favour of less obvious and more cryptic meanings. The suppression of the obvious features of the face, the obvious global letter, or the obvious literal meaning of a word may provide the device by which face-recognition performance is affected" (p1435).

The "grandmother cell" hypothesis is the idea that one neuron responds to the memory of grandmother. This is too simplistic, and though certain cells are linked to particular memories, a number of cells respond to a particular memory (ie: a set of "grandmother cells"). This is because a concept has many aspects or an individual is recalled in different situations (eg: grandmother sitting or standing) (Quiroga et al 2013).

8.4. FACIAL RECOGNITION

How many faces do people know - ie: remember? An answer based on evolution suggested 100-250 individuals (eg: Dunbar 1993) (ie: the assumed size of early human societies).

Jenkins et al (2018) put the figure at around 5000 faces on average from their experimental work. Twenty-five students in Scotland were asked to recall personally known faces based on a series of fourteen cues (eg: family, friends of family; commuters; professionals (eg: doctors, dentists)). Recognition was based on two criteria: "(i) be able to form a clear mental image of the face, or (ii) believe that they would recognise the face if they saw it" (p3). After one hour, the average number was 362 faces.

Based on the number of faces recalled over the time allowed (ie: 40 in first five minutes but 21 in the last five minutes), the researchers adjusted for unlimited time to calculate an average of 549.

Then the participants were cued to recall famous faces from twelve categories (eg: arts and media; politics; sports). After one hour, the average number recalled was 290.

Next the participants performed a recognition test for 3441 faces of famous people presented one at a time over a two-hour period. The task was to say "yes" or "no" to recognition. The researchers admitted that "any given 'Yes' response could instead reflect: (i) recognition of the image only, not the person, (ii) a feeling of familiarity without recognition, (iii) response to task demands (if participants suspect that they are not making enough 'Yes' responses), or (iv) motor error" (Jenkins et al 2018 p4). It was not required to know their name or anything about them. Recognition was about 30%.

The researchers found that around five times as many famous faces were recognised as recalled. So, they added the recalled faces (549 and 260), and multiplied by five to give around 5000.

However, there was great variety among the participants (in total from 1000 to 10 000). This is an interesting attempt to quantify the number of faces known, but is limited by a number of methodological decisions, including:

- Small sample size.
- Time allowed.
- Cue categories used for recall.
- Famous faces chosen in recognition test.
- "Jiggery-pokery" of multiplication of numbers.

The study feels like an attempt to quantify something that is very difficult to do, and to give an objectiveness to a subjective phenomenon. It is part of an "orgasm of numbers" (ie: pre-occupation with statistics as making things in psychology "true").

8.4.1. Fusiform Face Area

When viewing a face, a specific area of the brain called the fusiform face area (FFA) (Allison et al 1994) is activated. It is generally held that other areas of the brain are activated for object recognition, though this is disputed (Gauthier et al 2000). For example, some individuals with prosopagnosia, which is a problem with face recognition, also struggle with non-face object recognition. For instance, there is a case of a keen bird watcher who acquired prosopagnosia and also became unable to identify birds (quoted in Gauthier et al 2000).

Experiments have also shown that expertise with non-face objects involves the FFA. One such experiment by Gauthier et al (2000) involved eleven male car experts and eight male bird experts recruited at Yale University. The participants were shown images of faces, cars, birds, and familiar objects while undergoing neuroimaging.

The FFA was activated by faces in both groups (as expected), but the FFA was also activated to a lesser degree by the expert's objects - ie: birds for bird experts and cars for car experts. The familiar objects did not activate the FFA (as expected).

8.5. BRAIN-COMPUTER-INTERFACE (BCI)-BASED INTERVENTION

BCI-based neurofeedback systems use electrical signals from the brain. For example, in an attention training game, individuals receive feedback which allows them to modify their attention. This has been used with children with attention deficit/hyperactivity disorder (ADHD).

Qian et al (2018) reported a study with 66 boys with ADHD in Singapore, of which forty-four underwent three BCI-based training sessions per week for eight weeks. The game involved controlling an avatar running around an island, and the avatar ran faster if the participant was more attentive. The intervention group had a significantly greater reduction in inattention scores compared to the controls at the end of the study. Furthermore, brain scans showed changes in the brain after intervention.

8.6. HUMAN-ROBOT INTERACTIONS

Cross et al (2019) began: "As artificial intelligence and engineering technology continues to develop, we are encountering ever more sophisticated 'social' robots – not just in films and television series, but increasingly in real-world contexts" (p1). Human-robot interaction is a growing field in terms of understanding the social and cognitive neuroscience involved.

For example, Rauchbauser et al (2019) reported the neuroimaging of participants in conversation about a photograph with a human or robotic partner. Interacting with the human partner led to activity in areas of the brain related to social encounters (eg: theory of mind), while interactions with the robotic partner used executive and perceptual areas of the brain as well (Cross et al 2019).

8.6.1. Social Robotics

Social robotics is concerned with human-robot interactions, as in the use of robots in education as peer learners. However, robot-induced peer pressure has to be considered (Yang et al 2018). For example, Vollmer et al (2018) replicated Asch's conformity study with a group of small humanoid robots as the social pressure. Human children tended to conform, but not adults (appendix 8A).

8.7. APPENDIX 8A - VARIATION OF ASCH

Pendry and Carrick (2001) found that priming individuals about conformity or non-conformity beforehand influenced actual conforming behaviour.

Forty-eight undergraduates in the UK were divided into independent groups for the experiment. The participants read information in the priming task related to "Norman the punk" (non-conformity) or "Norman the accountant" (conformity). Then the participants individually underwent an Asch-like group conformity situation. This involved four people (three confederates and one participant) who stated out loudly the number of bleeps on a tape played to them. The participant was always last to speak after hearing the other estimates. The confederates were told to say a number between 120 and 125 (when there were actually 100 beeps).

A participant's estimate close to the group's estimate (120-125) was taken as conformity to the majority, and an estimate closer to 100 was a sign of non-conformity.

There was a significant difference depending on the priming. The mean estimate of the participants was 104 in the punk condition compared to 114 in the accountant condition (and 110 in the no priming control, and 103 in the solo estimation task control).

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9. OLDER DRIVERS

9.1. PERCEPTIONS

Musselwhite and Haddad (2010) outlined the known factors about the topic: "Driving is a complex task which requires many interlinking cognitive, perceptual and physiological processes... Reductions in physical and cognitive abilities is a natural part of the ageing process, and can negatively affect safety of driving in different ways... Older drivers are involved in collisions that generally occur in daylight, at intersection and at low speeds... They are less likely than other age groups to be involved in single-vehicle collisions... In addition, older drivers in particular have difficulty in making critical decisions under time pressure and dealing with immense traffic conditions. Hence, many of their collisions occur when drivers become overloaded with information when performing manoeuvres..., merging onto roads..., and older drivers are over represented in at-fault collisions at junctions and intersections, especially those with no traffic control (eg: traffic signals and lights) and those that involve right-hand turns (in the UK – ie: across the oncoming traffic)" (p181) [15].

But older drivers (ie: over 65 years old) are not a homogenous group, and their views on their driving may differ to the statistical data.

In relation to the latter, Musselwhite and Haddad (2010) collected data in southern England using focus groups, individual telephone interviews, and driver diaries with twenty-nine drivers aged 68 to 90 years old. The focus groups watched video-clips of driving situations (eg: driving in fog) and discussed them.

[15] The ability to attend to two tasks or sources of information, and executive function (which includes the abilities to plan, organise, and make decisions) are important in driving, but they deteriorate with age (Fernandes et al 2018).

More seriously, mild cognitive impairment (MCI) (taken as a mild dementia) leads to difficulties with navigation and decision-making in driving simulator studies (Fernandes et al 2018).

However, Fernandes et al (2018) noted that "despite studies showing potential cognitive difficulties in driving, the lack of specific evidence-based tests and criteria prevents us from judging drivers who are potential at risk. It is important to establish an evidence base that clearly determines the risk so that senior drivers can continue driving for as long as possible, thereby enhancing their independence and quality of life and minimising the risk to the drivers themselves and other road users" (p5).

Driver diaries were kept for 3-4 weeks, and included details of trips as well as problems that arose.

In summary, there was "a tendency for the participants to view themselves as having both better driving skills and a more appropriate attitude towards driving than when they were younger themselves and when they compare themselves to other drivers on the road, especially younger drivers. Further, they report that they are aware of and have a good ability to adapt their driving skills and behaviour to their changing physiology related to the ageing process" (Musselwhite and Haddad 2010 p184). But the diaries showed evidence of driving issues, including:

- Distractions from road signs, event signs and road-works.

- Problems with maintaining a constant speed within the speed limit (eg: lack of knowledge about speed limit; physical problems with seeing speedometer or keeping accelerator at required level).

- Fatigue and longer journeys.

- Reaction time.

- Lighting conditions on the road - eg: A man in his 80s said: "You can't judge the speeds so well when the suns glaring like that, so it makes junctions and roundabouts difficult and dangerous" (p186).

9.1. DRIVING CESSATION

Driving cessation (DC) can be a key event for an older adult, and may be due to declining health or increased nervousness behind the wheel, for example (Musselwhite and Shergold 2013).

DC is also associated with a reduction in quality of life. "It is not just a reduction in the ability to fulfil day to day needs as conveniently and quickly as possible that is missed when giving-up driving, but also an affective component including reduced independence and status and of being out of step with societal norms and roles... The car is linked to identity, self-esteem, autonomy, and prestige" (Musselwhite and Shergold 2013 p90).

Musselwhite and Shergold (2013) examined the process of DC with sixty over 65s in southern England and Wales in focus groups, individual interviews, and with travel diaries. Twenty-five participants were still driving, 32 had given-up, and three had never driven.

The in-depth individual interviews explored the motivation for DC, while the focus groups discussed the use of alternatives to the car. The month-long travel diary logged every journey, mode, distance, date, and time as well as any other interesting information.

The findings were divided into the process of DC, and the consequences of it.

a) DC - "The process of giving-up driving often seemed to stem from a significant realisation that driving may not be something that can be continued any longer" (Musselwhite and Shergold 2013 p93).

For example, a serious incident as described by this man in his 80s: "This woman stepped out in the road and I nearly hit her... I mean I'm only getting worse, so I think its time to stop" (p93). Or a more trivial one as outlined by this man aged 80 years old: "I got down the town and couldn’t park. I tried it again and again... and I thought that's it. That's enough. I can't do this anymore" (p93).

The personal realisation was coupled with comments from family members, for instance, as one son reportedly said: "look dad, you are getting a bit dangerous" (p94).

Then there was a period of contemplation, which included practical considerations like alternatives to driving to continue current activities. One woman stated: "So, the first thing I did was check how I can carry on getting to my yoga class, that was even before I started looking for something that'd get me to the shops" (p94).

b) Quality of life - Concentrating on fifteen individuals who reported no dramatic decline and six a dramatic decline in quality of life after DC. The former group adapted their lives to new modes of travel or to less travel. "Individuals with a good quality of life post-car almost exclusively carried out a great deal of planning for a life after driving" (Musselwhite and Shergold 2013 p95). Family support was also important.

The six individuals were male, and their unhappiness with DC had wider significance - eg: "I suppose that's it now. A general sense of life being over... I mean what have I too look forward to really. It does get me down. Everything I enjoyed is not possible to do anymore" (81 year-old man; p95). It has been suggested that "the car extends masculinity and normalness for men well into later life which suggests reluctance to let go of something fundamental to their identity. For females driving is more about enabling multiple identities, fulfilling tasks, and roles" (Musselwhite and Shergold 2013 p97).

Key to a positive or negative experience of DC was perceived control - ie: who is felt to make the decision. Individuals who planned and chose to stop driving were happier than those where DC was perceived as forced upon them (eg: through illness). "Owning the decision" was important "irrespective of the actual extent of control that they exercised over it, and some may even retrospectively alter their perception of how involved they were in the process" (Musselwhite and Shergold 2013 p97).

Sollner and Florack (2019) noted that studies have "shown that older drivers often apply effective self-regulatory strategies to cope with the decreases in their abilities... However, self-serving biases might prevent older drivers from identifying the full scope of critical behaviours and determining when to stop driving" (p222). If driving abilities are declining, does anybody tell the ageing driver?

For example, in a US survey of over 4000 over 50s, only 2% stated that they had received critical comments about their driving (Coughlin et al 2004) [16]. "Providing negative feedback is unpleasant and thus often leads to reluctance and hesitation on the part of the person giving the feedback... and defensive responses on the part of the person receiving it... Furthermore, it might put pressure on relationships" (Sollner and Florack 2019 p219).

From the commenters' side, Sollner and Florack (2019) online surveyed 221 German middle-aged adults as to whether they had ever spoken to an older adult about declining driving abilities. One hundred and ten respondents said that they had observed declining abilities in mostly a parent's driving (but also a friend), and sixty-five of them had provided feedback to the driver. The main reasons for the feedback were concerns about safety for the driver, passenger or other, or having observed a clear driving error. Those who had not given feedback were mostly worried about a negative reaction from the driver.

Respondents who held positive age stereotypes [17] believed the feedback would be effective (appendix 9A).

Caragata et al (2019) investigated the response to family comments by thirty-seven older drivers (over 70 years old) in Vancouver, Canada. The participants were asked to think of comments made to them about their driving, and these were organised into four categories - statements supporting continued driving, or statements to modify, reduce, or stop driving (table 9.1).

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[16] Note that "a broader sample of elderly drivers had been interviewed, so the sample was not limited to drivers with declining driving abilities" (Sollner and Florack 2019).

[17] More likely to agree with items like, "older people find the right solution for important life issues", and "older people can deal with everything well on their own".

Statement Type	Examples
Supportive	• "I feel safe driving with you" * • "You're as good a driver as anyone"
Modify driving	• "You drive too fast" • "You are driving too slowly"
Reduce driving	• "Your reflexes are getting slower" • "Your driving has deteriorated"
Stop driving	• "How would you feel if you hit a child?" * • "I don't want you to drive your grandchild" *

(* = highest influence statements)

(Source: Caragata et al 2019 table 3 p492, tables 4-6 p493)

Table 9.1 - Examples of statements about driving.

Twelve of each type of statement were randomly organised into the 48-item Subjective Ranking Task (SRT), and the participants rated how much each statement would influence them (on a four-point scale of "no influence" to "a lot of influence"). Questionnaires about driving were also completed.

Around 60% of the statements were rated as likely to influence the individual's driving. "Statements aimed at supporting the participants to continue driving, and statements aimed at getting them to reduce driving were rated as having the highest overall influence, with 62% of statements in each of these themes being rated as high influence. Statements aimed at getting participants to stop driving was supported at a slightly lower level (58%). Furthermore, statements encouraging participants to modify their driving habits had the least perceived influence (52%)" (Caragata et al 2019 p491).

In terms of the emotional response to the comments, the participants "said they would 'think about' what the family had said and 'be more aware' of how they were driving, for example, making sure they were shoulder checking and being more aware of pedestrians. Most participants said they would be 'surprised', 'shocked', 'upset', 'hurt', and sometimes insulted if someone commented on their driving. Most stated they would not be angry with the other person whom they believed would be acting primarily out of concern for their (the elder's) safety. Nonetheless, a few participants became indignant with an 'It's none of their business, I make my own decisions' attitude" (Caragata et al 2019 pp491-492).

This last response was more common among older drivers who scored highly on the Self-Report Habit Index (SRHI) (Verplanken and Orbello 2003). This measured driving as a habit (eg: frequency; self-identity as a driver; use of other means of transport). "This demonstrates that individuals with strong driving habit are less influenced by information provided by family, and less likely to change their driving. This conclusion is supported by the finding that, among the high-habit group, the highest proportion of statements chosen as high influence supported their continued driving and the fewest statements chosen encouraged them to modify their driving" (Caragata et al 2019 p496).

Caragata et al (2019) made this comment: "Advice on how to form new habits has also been shown to be more effective at changing behaviours than critiquing the undesired behaviour... Thus, it may be more productive to introduce new transportation mode habits rather than to attempt to change old driving habits. For example, an elder who habitually drives for groceries may reject suggestions by family to take a taxi; instead, a family member could introduce a new mode of transportation by starting a new habit of using a taxi every week to see a movie with the older adult. Over time, the new habit of taxi use may supersede old habits of driving to other destinations" (p496).

Female participants reported more influence from the comments than male participants, and responded to the comments using the extremes more often (ie: "no influence" or "a lot of influence").

Four factors were found to increase the influence of the family's comments (Caragata et al 2019):

- The commenter must have first-hand experience of the driver's behaviour.
- The commenter must be perceived as a good driver by the older adult.
- There is trust between the commenter and the driver.
- Specific examples of behaviour were considered.

9.3. APPENDIX 9A - CAR AND DRIVER STEREOTYPES

Davies and Patel (2005) considered the role of stereotypes in perceived driving generally in three experiments.

In the first experiment, 24 undergraduates at an English university rated eight different types and seven colours of car, and six drivers (based on age and gender) on a seven-point scale from "very passive" to "very aggressive". The least aggressive items were the Citroen 2CV make of car, the colours beige and green, and elderly female and male drivers, while the most aggressive were the Ford Escort XR3i, the colour red, and young male drivers. "It is evident that, for this sample at least, stereotypes of perceived aggressiveness regarding cars, their colours, and the age and gender of drivers are present and pervasive" (Davies and Patel 2005 p49).

Experiment 2 investigated these stereotypes in relation to the perceived culpability in a road accident. Eighty-one adults in England read a story about a collision between a red Ford Escort XR3i driven by a young man (high aggression stereotype) and a green Citroen 2CV driven by an elderly man (low aggression stereotype), where the cause was ambiguous. Statements by the two drivers were read in different orders, and the driving speed claimed was varied. A seven-point scale was used for judgment of blame. Overall, "the red XR3i driven by the young man was seen as more responsible for the accident than the green 2CV driven by the elderly man" (Davies and Patel 2005 p53). This effect was stronger when the older driver's version of events was read first.

In the third experiment, the researchers varied the make and colour of the car, and the age of the driver in a scenario of a collision between a car and a van that injured a cyclist. Ninety-six undergraduates were divided into eight conditions based on two driver ages (young/old), two types of car (XR3i/2CV), and two colours (red/green). In contrast to Experiment 2, the attribution of blame did not show evidence of a stereotype. Davies and Patel (2005) explained that "when the stereotypes were disaggregated, it is evident that the various components do not combine in a uniform or simple way. A red car added nearly 5 mph (8.05 kph) to speed estimates if the driver was a young male, but not if he was elderly. Compared to the elderly man, the young driver was perceived as driving faster behind the wheel of a 2CV, but not when both age groups were seated in an XR3i. Thus, while stereotypical information influenced judgments of speed and road position, it appeared that the three elements of the stereotype interacted and moderated each other in quite subtle ways – which element of a stereotype was activated depended upon the context and additional information provided" (p58).

These experiments supported the idea of car and driver stereotypes, but the elements of the stereotype interacted in "quite subtle, but significant ways" (Davies and Patel 2005 p59).

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