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Cognition 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.

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1. THE BRAIN AND MULTI-SENSORY PROCESSING

1.1. MULTI-SENSORY PROCESSING

The brain receives signals about the environment from multiple senses simultaneously, and faces the challenge of integrating that information. This is the "binding" problem - "inferring which signals come from a common source and thus should be integrated. At the same time, it must also estimate the reliability of each signal to determine how much influence it should have on the perceptual judgement. Effective decision making thus requires the brain to grapple with the uncertainty associated with various sensory signals as well as their causal relationship" (Fetsch and Noppeney 2023 p1) [1].

Stange et al (2023) explained: "The predictive coding framework proposes that top-down predictions and bottom-up sensory input are compared at sensory processing stages; if predictions do not match the actual sensory input, this framework assumes that an error signal is generated which travels downstream to update representations about the world. In line with these assumptions, both brain imaging and electrophysiological studies have revealed enhanced neural responses to unexpected compared to expected sensory events, which were interpreted as error signals" (p1).

[1] Zeng et al (2023) described the example where "a prey urgently needs to confirm whether a cloud of spots behind the tussock are from a predator in order to decide whether to stay or flee. This task can be even more difficult when visual information is vague, for example, on a foggy day, or during the evening time. There are two possible ways to facilitate making more correct and faster choices. One is to observe whether these spots move coherently. The other is to collect evidence from other sources, such as footprints or smell, at the same time. This process of accumulating sensory evidence across time and modalities into categorical decisions to select the following course of action is defined as multi-sensory decision making (MSDM)" (p1).

Research on the brain's decision making processes in perception can be divided into three main themes (Fetsch and Noppeney 2023):

i) The dynamic nature of the decision process - The sensory information "usually arrives not as a single snapshot but a temporal sequence or stream of information, and therefore we must decide not only what but also when to commit to a decision" (Fetsch and Noppeney 2023 p2).

ii) The role of top-down factors - The decision making process is influenced by top-down factors like learning, expectations, and goals and intentions. The alternative is bottom-up processing which uses the sensory information alone.

iii) Dealing with uncertainty - "Sensory information is imperfect, owing to limitations in our sensory apparatus, and to noise in both the physical events being transduced and the neural representation thereof. For this reason, perceptual judgements are productively studied within a framework of decision making under uncertainty" (Fetsch and Noppeney 2023 p2).

Multi-sensory integration (MSI) (table 1.1) involves many areas of the brain (both cortical and sub-cortical). Choi et al (2023) noted different types of MSI including speech MSI (the integration of sound of speech and vision of mouth movement), spatial MSI (information from different spatial locations), and temporal MSI (eg: audio and visual information at different times).

The knowledge about the brain and MSI comes from three main sources - studies of the anatomy, measurement of electrical activity (electrophysiology), and neuroimaging experiments. The first brain area to be studied in detail was the superior colliculus (SC), which is a midbrain structure, and visual perception was investigated with single cell recording in anaesthetised cats (Meredith and Stein 1983) [2]. Subsequently, the SC was found to be involved in MSI (ie: auditory and visual

[2] The early work by Stein et al (1975) found that "neurons in deep and middle, but not superficial layers of SC, respond to multi-modal (visual, auditory and somatic) stimuli. Importantly, the multi-sensory responses are much stronger than when only one modality is stimulated, often leading to a super-additive pattern (i.e. 1 + 1 > 2)" (Zeng et al 2023 pp1-2). Such early experiments, however, were performed on anaesthetised animals pr awake but passive ones. More recent studies measure neural responses in awake animals performing typical behaviours (eg: using a visuo-vestibular virtual-reality system). "In a typical experiment, awake monkeys are required to report whether their experienced heading direction is leftward or rightward compared with dead ahead by making a saccadic eye movement toward choice targets at the end of each trial" (Zeng et al 2023 p2).

inputs from a variety of brain areas. When neurons in the SC were destroyed (as in experiments with cats, say), the animals could not accurately orientate towards stimuli (Choi et al 2023).

Research has shown the role of areas of the different cortices, the thalamus, and the amygdala in MSI (Choi et al 2023).

- Multi-sensory processing - "a host of brain functions that deal with multiple sensory modalities' inputs and states — for a variety of different purposes, including integration, suppression...).
- Multi-sensory integration - "combining multiple sensory measurements from different modalities into a unified estimate of the stimulus".
- Multi-sensory suppression - "the neuronal or behavioural responses to a stimulus are reduced by the presence of another stimulus from a different modality".
- Multi-sensory interactions (or dependencies)- "when the response or measurement from one modality depends on the state (or input) of another".
- Multi-sensory causal inference - "probabilistic inference regarding the origin(s) of the experienced stimuli".

(Source: Zaidel and Salomon 2023 table 1)

Table 1.1 - Key terms.

Recent research is challenging long-held views about perception. Pennartz et al (2023) outlined one of them - "the canonical notion that the visual cortex is uniquely positioned to process only visual information, acting as a relay station to transmit this to higher order cortical and thalamic areas for decision making and other executive functions..." (p1). Work with rodents suggests that other sense information is also processed in the visual cortex and helps with visual perception, and that visual perception overall involves a wider network of brain areas (the "extended visual system"; Pennartz et al 2023).

Taking the first of the two challenges, neurons in the primary visual cortex respond to input from other senses (eg: auditory-evoked). In other words, there is multi-sensory processing in this area of the brain. But Pennartz et al (2023) made this point: "one may consider the alternative stance that the visual cortex is no

longer strictly 'visual' given all other inputs, and is therefore better characterised — together with other sensory cortical domains — as 'multi-sensory cortex' [Ghazanfar and Schroeder 2006]. However, as visual cortical lesions cause blindness but not deafness (and vice versa for auditory cortical lesions...), the specific causal importance of visual cortex for visual perception needs to be accommodated as well" (p8).

The "extended visual system" includes the visual cortex (Pennartz et al (2023) preferred to call the "photically driven cortex") as well as neurons in the prefrontal cortex, posterior parietal cortex, auditory cortex, and motor and somato-sensory areas of the cortex. The "cortical regions causally linked to non-visual sensory modalities can be considered to form satellite nodes contributing to the extended visual system..." (Pennartz et al 2023 p10). Zhang et al (2016) have mapped a wide-ranging visual network in the mouse brain.

A key concept behind these ideas is "predictive processing", "holding that the perceiving brain forges best-guess representations (inferences) of the causes of sensory inputs. Thus, the brain is not tasked with exactly 'copying' features from the external world into perceptual systems, but does a much more constructive job: building an internal, representational model of what is likely causing the inputs relayed to the brain from the sense organs" (Pennartz et al 2023 p2) (appendix 1A).

1.2. DYNAMIC NATURE OF THE DECISION PROCESS

Flexibility in MSI is key as inputs vary in time and space across the different senses (modalities). A number of influences occur here, including (Choi et al 2023):

i) Age - Age-dependent changes in the brain and MSI have been mapped in electrophysiological recordings of cat brains, for example (Wallace and Stein 1997). While in human infants, three stages of the development of MSI have been reported - "immature" (less than one month old) (respond to stimuli based on intensity), "broadly tuned" (5-8 months old) (increased attention to relevant stimuli), and "normally tuned" (12 months old) (eg: ability to perceive and respond to speech above other stimuli). Fine tuning of the MSI continues in childhood and into adulthood (Choi et al 2023).

ii) Experience/learning - Feedback from previous experiences with particular stimuli influence MSI as

shown in neuroimaging experiments. For example, human participants are shown objects with sounds (congruent or incongruent) while the brain activity is measured. This is known as the "audio-visual object association task" (eg: Naumer et al 2009).

iii) Internal state - eg: stress. For example, mice had to navigate a T-maze in a situation of "audio-visual conflict" (ie: auditory and visual stimuli have opposite meanings) while stressed or not. When stressed, auditory stimuli were more important compared to visual stimuli as more important when not stressed (Choi et al 2023).

iv) Deficits in MSI in neurodevelopmental disorders - eg: autism. In the "temporal order judgment task", where visual and auditory stimuli are randomly presented and the task is to say which came first, children with autism are less accurate than healthy controls (Choi et al 2023).

"To navigate and guide adaptive behaviour in a dynamic environment, animals must accurately estimate their own motion relative to the external world. This is a fundamentally multi-sensory process involving integration of visual, vestibular and kinaesthetic inputs" (Jerjian et al 2023 p1). This is "self-motion perception". Time is important here as the information coming to the senses is constantly changing as we move. Jerjian et al (2023) added another key variable - certainty (ie: "the degree of confidence in a multi-sensory decision"; p1) [3] [4].

Jerjian et al (2023) used the example of rock-climbing (at an indoor centre): "A successful, fast, climb to the top is facilitated by estimating an optimal route from an initial vantage point (or several) on the mat. During each movement across or up the wall, multiple sensory inputs are available to the brain to guide a successful climb: vestibular signals arising from motion

[3] Zaidel and Salomon (2023) commented that "internal sensory information conveyed from proprioception (eg: where are my eyes looking?), vestibular (eg: how is my head positioned?) and interoception (eg: the sound is external and not my heartbeat) is seamlessly and implicitly taken into account to allow the explicit sensory experience of the world around us. All our sensory experiences are in actuality based on both internal and external multisensory information" (p1).

[4] Zaidel and Salomon (2023) emphasised that "sensory systems are not passive receivers. Rather, they are part of sensorimotor loops. Not only do the movements we make influence sensations, humans and animals actively move to sense the environment (active sensing). We move our eyes to probe the visual scene and move our hands to generate tactile input. This means that sensory signals can only be interpreted within a sensorimotor context, in addition to the mixing of signals from multiple senses. Thus, the observer must fundamentally determine whether each sensory observation is from an external (versus internal, self-generated) source to even be considered for integration" (p3).

of the head through space; visual signals from motion of the scene across the retina; proprioceptive and tactile signals indicating the position and motion of the limbs and the quality of a hand- or foothold. Small or slippery holds may render tactile information unreliable. Visual input could be ambiguous or uncertain, for example if one is climbing on an overhang or with reduced ambient light levels. Depending on the frequency and amplitude of head motion, vestibular inputs may be unreliable or fail to disambiguate translation from tilt. Thus, to estimate their ongoing motion with respect to the goal and select actions accordingly, the optimal climber will use information from all available sources, at each moment instinctively leaning more heavily on the more reliable ones" (p1). Fast decision-making is the time element here, while "a climber's confidence that they have an accurate self-motion judgment is also critical" (Jerjian et al 2023 p1).

A number of cortical areas are known to be involved in human self-motion perception in this sort of activity, including the dorsal medial superior temporal area, and the ventral intra-parietal area (Jerjian et al 2023).

The combination of visual and auditory information has been studied via "eye movement-related eardrum oscillations" (EMREOs) [5]. It was found that information about eye position and movements produced activity in the "predominantly auditory brain regions such as auditory cortex and the inferior colliculus during responses to sound stimuli" (Lovich et al 2023 p2). This led researchers to reason that "information about eye movements could be conveyed via the descending pathways to the motor actuators within the ear, such as the middle ear muscles and the outer hair cells, and that, just like with conventional otoacoustic emissions and middle ear reflex testing, the impact of such signals might produce movements of the eardrum that could be detected by microphones in the ear canal" (Lovich et al 2023 p2).

EMREOs occur with eye movements, sometimes preceding them and continuing after for several tens of milliseconds. EMREOs provide precise information about the direction and amount of eye movement (Lovich et al 2023).

EMREOs have been found in rhesus monkeys and humans, which is not surprising as "the two species have similar visual and auditory acuity and similar eye movements. They are also known to integrate visual and auditory space in reasonably similar ways, showing similar

[5] Discovered by Gruters et al (2018).

thresholds for fusing versus distinguishing visual and auditory locations" (Lovich et al 2023 p2).

The exact role of EMREOs in the co-ordination of information "has not yet been established" (Lovich et al 2023 p7).

1.3. TOP DOWN FACTORS

Newell et al (2023) began: "Object categorisation is a fundamental cognitive ability that allows us to efficiently recognise and interact with the content of our environment despite variability in the encoded object properties from one instance, or from one example, to the next. The processes underpinning category formation are thought to be mediated by both sensory-driven information and prior knowledge from memory, although how object categories emerge based on multi-sensory features is poorly understood" (p1).

Concentrating on prior knowledge, "predictive coding models" propose that "best estimates" of objects (eg: templates) are stored in memory, which can be updated. An alternative is "statistical or Bayesian models", which argue that "the brain combines information from different senses in an optimal manner, based particularly on the inferred causality or reliability of the information from each modality" (Newell et al 2023 p3) (ie: a combination of both bottom-up and top-down processing).

One problem is understanding how object categories form in the first place. This includes the study of infants and early development, and how categories are organised in memory.

In terms of research, Broadbent et al (2018), for example, presented 6-10 year-olds with familiar objects in auditory only, visual only, and audio-visual conditions. For all ages, recognition was best in the combined condition, but performance improved with age. Such research is taken to suggest that "improved sensory and perceptual precision with development likely underpins multi-sensory integration for categorisation" (Newell et al 2023 p6).

Studies with adults involve novel objects, and how they are categorised together (eg: Carvalho et al 2021). They show how information from different senses can "act as the 'glue'" (Newell et al 2023 p8) in object categorisation, but also where information from one sense is uncertain. "Thus, hearing a bark will help recognise the shape of a dog if visual information is compromised (ie: if the image of the dog is partially occluded or

blurry)" (Newell et al 2023 p8).

1.3.1. Meta-Cognition

Maynes et al (2023) distinguished three types of multi-sensory experience:

i) Congruent signals - "a single source in the environment giving rise to sensations in two or more modalities at the same time. For instance, when you talk to another person, you see their lips move and hear the sound of their voice, and this information arises from one source" (Maynes et al 2023 p2) (appendix 1B).

ii) Integrated signals - the brain receives conflicting information but integrates the information as a single source (eg: ventriloquism illusion).

iii) Segregated signals - information is received from more than one source, and the brain processes them as separate sources.

Maynes et al (2023) compared the first two types using the "sound-induced flash illusion". This has two versions - the "fission" version ("if observers are presented with two brief beeps and one visual flash, they often report seeing two visual flashes"; p2), and the "fusion" version ("if observers are presented with one beep and two visual flashes, they sometimes report seeing one visual flash"; Maynes et al 2023 p2).

Forty-six US undergraduates were presented with combinations of 0-2 flashes and 0-2 beeps in unisensory (eg: one beep only) and bisensory conditions (eg: 2 beeps/1 flash) (table 1.2). The presentation of the information was rapid (eg: 50 ms between flashes), and the participants performed six blocks of 40 trials. Participants rated their confidence level of accuracy after each trial.

Accuracy in perception was higher for unisensory and congruent bisensory conditions (eg: 2 beeps/2 flashes), and lower for bisensory illusion/incongruent conditions (eg: 2 beeps/1 flash) [6]. Confidence level also showed the

[6] Zaidel and Salomon (2023) asserted: "Put simply, there is no, nor has there ever been, true unisensory stimulation" (p2). They explained this statement: "Even when one's eyes are fixated, and the head is stationary, proprioceptive signals from the eye muscles and vestibular signals regarding head position continue to bombard the brain. In complete darkness, the visual cortex remains highly active (and this activity even differs with eyes open or closed. Interoceptive and tactile signals are always present. Thus, 'unisensory' perception is a misnomer. In 'unisensory' experiments (or measurements), signals from the sense being probed are always received in combination with signals from the other senses and

same pattern. This suggested that confidence level, which was taken as a measure of metacognition, helps in distinguishing between congruent and illusory/incongruent multi-sensory information.

Maynes et al (2023) proposed that metacognition (defined as "the capacity to monitor the quality and fidelity of one's own perception"; p1) relates to information-seeking. They stated: "Specifically, metacognition may link to information-seeking via some type of inverted U-function, where extremely high or extremely low confidence is associated with little information-seeking (if you know what something is, or information comes from an extremely noisy source, it may not be worthwhile to pursue further information), but intermediate levels of confidence may be linked to greater information-seeking to resolve ambiguities in stimuli. In this sense, perhaps lower levels of confidence for integrated multisensory stimuli could drive further information-seeking to determine whether the integrated signals truly came from a single source, or whether further exploration could lead to a more accurate inference about multiple sources of information being present" (Maynes et al 2023 p5).

Condition	Type	Mean confidence (out of 4)
1 beep (1B)	Unisensory	3.71
2 beeps (2B)	Unisensory	3.69
1 flash (1F)	Unisensory	3.38
2 flashes (2F)	Unisensory	3.21
1 beep/1 flash (1B1F) (Congruent)	Bisensory	3.38
2 beeps/1 flash (2B1F) (Incongruent/"Fission" illusion - 2 flashes perceived)	Bisensory	3.06
1 beep/2 flashes (1B2F) (Incongruent/"Fusion" illusion - 1 flash perceived)	Bisensory	3.15
2 beeps/2 flashes (2B2F) (Congruent)	Bisensory	3.22

Table 1.2 - Different experimental conditions of Maynes et al (2023).

interpreted within that multisensory context. Thus, while we may decide to manipulate sensory signals and ask for decisions in one sensory domain in our experiments, we are always in practice impacting multiple sensory streams" (Zaidel and Salomon 2023 p2).

1.4. UNCERTAINTY

Multi-sensory processing involves combining sensory cues from the same event, but distinguishing cues from different events. This is the "causal inference problem" (Marly et al 2023). To deal with the uncertainty, one hypothesis is that the brain has "conflict monitoring mechanisms" (eg: in anterior cingulate cortex) as part of the "cognitive control network" (Marly et al 2023).

Certainty is greater when the sensory cues are clearly from the same event or show obvious disparity (ie: from different events). It is the "grey area" in between where uncertainty is higher, and this is studied in experiments. For example, the "ventriloquist illusion paradigm" [7], where "light and sound are presented from a range of locations, and participants have to locate either one or both stimuli. Sound location is often 'captured' by the light (ie: the sound is perceived as coming from, or near, the position of the light) when spatial disparity is small" (Marly et al 2023 p2).

Marly et al (2023) measured the electrical activity of the brain (using electroencephalography; EEG) in situations of perceptual conflict using the above paradigm. Visual and auditory stimuli were presented from five different positions, and the task was to state the location of the stimuli as quickly as possible. There were unisensory conditions (ie: sound or vision only) and a multi-sensory condition. Reaction time was quicker when the visual and auditory stimuli came from the same position or clearly from different directions. Reaction time was slower when there was uncertainty, and particular electrical activity (increased theta waves) was measured, "both indicative of conflict" (Marly et al 2023 p1).

The findings fit with previous studies that suggest a series of stages in multi-sensory processing. Marly et al (2023) explained that "multi-sensory perception would begin with the computation of unisensory estimates in sensory areas during the first 150 ms, followed by a fused estimate in posterior association brain regions, 100 ms to 260 ms, and finally the computation of the causal inference estimate that would involve anterior regions starting as soon as 200–300 ms (timings vary between studies). The observed peak of theta in our study would fall between the timing of the generation of the

[7] Another audio-visual illusion used in research (eg: Meijer and Noppeney 2023) is the "McGurk-Macdonald illusion" (McGurk and Macdonald 1976). This is where incongruent sound and vision is perceived as an entirely different sound - eg: the sound "Ba" and lips seen making the "Ga" sound together is perceived as "Da".

fused estimate and the generation of the causal inference estimate. This timing fits well with the idea that the origin of the conflict signal is the arbitration between internal causal models, prior to the emergence of the final multi-sensory estimate" (p11).

Multi-sensory information from vision and touch (haptic) about an object has been studied experimentally, for example by Badde et al (2023) Twenty-six student-participants were presented with objects of differing roughness or slant in three conditions - vision only, touch only, and combined vision-touch. The latter condition also included matched and unmatched versions (ie: seeing and feeling the same or different objects).

There was great variety between individuals in the integration of visual-haptic information. "For example, a perceived mismatch between visual and haptic roughness would not deter the observer from integrating visual and haptic slant. These results indicate that participants based their perceptual judgements on a feature-specific selection of information, suggesting that multi-sensory causal inference proceeds not at the object level but at the level of single object features" (Badde et al 2023 p1).

Crossing a busy road is a good example to use to understand uncertainty in multi-sensory perceptual decision-making. The observer must perceive the oncoming traffic and estimate approach time in relation to the time to walk/run across the distance of the road. "Efficient decision-making requires accounting for sources of uncertainty (noise, or variability). Many studies have shown how the nervous system is able to account for perceptual uncertainty (noise, variability) that arises from limitations in its own abilities to encode perceptual stimuli. However, many other sources of uncertainty exist, reflecting for example variability in the behaviour of other agents or physical processes" (Aston et al 2023 p1).

So, uncertainty can be divided into internal/ intrinsic and external/extrinsic (Aston et al 2023). Internal uncertainty describes the limitations of the perceptual system (eg: vision and the amount of light as in crossing the road in near darkness), while external uncertainty refers to the environment (eg: the speed of individual drivers). "Human perceptual systems may be well equipped to account for intrinsic (perceptual) uncertainty because, in principle, they have access to this. Accounting for external uncertainty is more

challenging because this uncertainty must be learned" (Aston et al 2023 p1).

Virtual reality allows participants to navigate around an environment which can be varied (eg: objects stationary or moving; self/observer stationary or moving). The mistakes in perception (ie: illusions) can be used to understand the process of perception. For example, accuracy in navigating around a virtual environment varies depending upon perceived self-motion, object-motion, and the apparent velocity of movement. In their experiments, Noel et al (2023) found that "humans are more likely to report moving targets as stationary at high velocities during concurrent self-motion. Similarly, during concurrent self- and object-motion, observers navigate to locations closer to the initial target location, as if the target were not moving" (p9).

The virtual environment was manipulated such that the images on the retina could be due to self-motion, object-motion, or a combination of both. There is a high level of uncertainty and the brain is making decisions in continuous time.

1.5. APPENDIX 1A - PREDICTIVE PROCESSING AND AESTHETICS

Martindale (2007) observed: “How has it come to be that we know rather more how people remember nonsense syllables and far less than we should like to know about how they create and understand art?” (quoted in Leder and Pelowski 2023).

From a "fleeting, messy, ever-changing bundle of light waves, sound waves and odour molecules" (p1) we make sense of the environment, but more than that, we make complex sense in what can be called aesthetic experience (ie: beauty and art) (Frascaroli et al 2023).

But trying to explain what we find beautiful has interested philosophers over history. The "classic theory" or "great theory" of beauty emphasises the "ordered arrangement of parts" - ie: "we experience beauty whenever we perceive that different elements in our sensorium (the notes of a musical piece, the pigments on a canvas, the features of a landscape) stand in ordered relationships with one another and conspire, as it were, to create a meaningful whole — a structure or pattern that we can grasp. Experiences of beauty, in other words, would be moments of sudden clarity about the structure of our world: moments where everything makes sense, everything clicks into place, everything is

exactly as it should be, and more coherence, unity, consistency among disparate things is achieved. Artworks, in turn, would be objects specifically designed to afford these experiences" (Frascaroli et al 2023 p2). This idea has been taken up by contemporary neuroscience and psychology (eg: Ramachandran and Hirstein 1999) (or "neuro-aesthetics") - "the brain rewards progress toward organising the perceptual field into a meaningful configuration" (Armstrong and Detweiler-Bedell 2008 quoted in Frascaroli et al 2023).

An alternative idea on cognitive science is based on predictive processing (PP) (or predictive coding theory). Basically, the brain is testing hypotheses about the incoming signals to the senses to reach a conclusion about what is out there. "Prediction errors" help steer the brain to a better prediction. "The oscillations in uncertainty in its hypotheses about the structure of its world are therefore direct signals about how well it is doing in ensuring its continued existence as a viable model of that world. This means that perception and cognition are always soaked with affect, tied as they are with the hope that the world will reveal some structure and further our existence. What we call aesthetic pleasure, so the PP story suggests, is the positive affective feedback that we get when we are more successful than usual in making sense of our environment (or, in PP terms, in reducing prediction error...). Aesthetic pleasure is, in other words, the mark of a cognitive and existential conquest" (Frascaroli et al 2023 p4).

Frascaroli et al (2023) presented the case for a PP understanding of aesthetics, and introduced a special issue of the "Philosophical Transactions of the Royal Society B".

One of the articles (Leder and Pelowski 2023) offered some caution: “We are happy that PP has opened exciting arguments in aesthetics, with suggestions that this might unlock how we perceive and respond to art. At the same time, however, while the promise of PP is slowly advancing from ‘biologically plausible’ to concrete, the movement from metaphor to actual mechanism appears even slower, especially in aesthetics research” (p2).

A criticism of PP generally is the so-called “Dark Room Problem” (eg: Sun and Firestone 2020), which suggests that “if behaviour was driven only by the imperative to minimise uncertainty, organisms like us would always be found in situations that are minimally

uncertain and that preclude violations of our predictions" (Constant et al 2023 p1). This would also preclude creativity.

Constant et al (2023) offered a solution that they called the "Enlightened Room Problem". They explained: "Creativity emerges from various degrees of interplay between predictive brains and changing environments: ones that repeatedly move the goalposts for our own error-minimising machinery. By (co)constructing these challenging worlds, we effectively alter and expand the space within which our own prediction engines operate, and that function as 'exploration bubbles' that enable information seeking, uncertainty minimising minds to penetrate deeper and deeper into artistic, scientific and engineering space" (Constant et al 2023 p1).

1.5.1. Aesthetic Experience

Van de Cruys et al (2023) began: "How to account for the powerful effects of art on us? For example, what do people mean when they insist that a piece of art (be it literature, visual art or music) has helped them through difficult times? Clearly, they do not mean this in the literal sense of 'helping': art does not help like anti-biotics do, eliminating the worldly cause of distress. Rather, art relieves distress by modifying our mental states — our construction of the brute facts of the world — and with that it opens up new opportunities for action. It provides the means for articulating, understanding and, ultimately, accepting or transforming our situation and ourselves" (p1). This is a way of describing the "aesthetic experience".

But how to pin down this experience? Shaviro (2012) described it this way in comparison to desire: "Desire is how the self projects itself into, and remakes, the world; aesthetic feeling is how the world projects itself into, and remakes, the self" (quoted in Van de Cruys et al 2023).

Van de Cruys et al (2023) outlined four properties of the aesthetic experience based on the tension between receptivity (the willingness to change) and incomprehensibility towards the artwork:

i) It is "a process, rather than a moment or instantaneous appraisal of a static thing" (Van de Cruys et al 2023 p2).

ii) There are both positive and negative emotions.

iii) There are individual differences in what causes the experience.

iv) It is an unrepeatable experience. "An aesthetic experience cannot be relived in the same way, because it consists in a change in one's relation to the object that prompted it... This does not mean that the same work cannot give rise to new aesthetic experiences, but rather that..., these will be new instances caused by different generative processes sharing a similar structure" (Van de Cruys et al 2023 p2).

Muth and Carbon (2023) used the term "Semantic Instability" (SeIns) to describe an experience "marked by a plurality of meanings, an unfulfilled potential for a determinate interpretation or even meaningful contradictions" (p1). SeIns "can generate aesthetic hedonics and interest" because art perception is different to problem-solving in that "we typically integrate contradictory elements dynamically and without the ultimate goal of resolving the contradictions" (Muth and Carbon 2023 p1).

1.5.2. Aesthetic Appreciation

The individual is faced with the anxiety of uncertainty (ie: a drive to avoid anxiety), but also the need to pursue new information for survival. Barbieri et al (2023) suggested that aesthetic appreciation creates a positive feeling that drives curiosity and so overcomes the anxiety of uncertainty. Barbieri et al (2023) put it thus: "We propose that aesthetic appreciation might have evolved as a self-generated intrinsic reward motivating us to tolerate arousing sensory uncertainty to favour the search for novelty, learning and change" (p3).

These researchers reported two studies to support this view. In one of the studies participants listened to different types of classical music, and expressed an aesthetic judgment (AJ) about each piece. They also completed a measure of general anxiety afterwards. There was a negative relationship between AJ and anxiety score.

In another study, fifty-one Italian adults watched magic tricks while listening to classical music or white noise. After each trick, the participants were asked to report their interest in the solution of the trick. Then whether they would play a gamble game to discover the solution, but receive a mild electric shock if lost. Willingness to gamble was classed as curiosity. The self-

reported level of interest in the solution did not vary between conditions, but participants in the classical music condition were more willing to gamble.

Barbieri et al (2023) summed up: "These results were consistent with the idea that aesthetic appreciation could act as a 'valve', prompting the individual to perceive curiosity (ie: to consider novelty as a valuable opportunity to acquire new knowledge) rather than anxiety (ie: to consider novelty as a risk to be avoided)" (p1).

1.5.3. Aesthetic Judgment

Yoo et al (2023) concentrated on "aesthetic judgment", which they saw as a "mixture of cognitive and affective processes... The cognitive elements encompass recognition of basic elements of the artwork and beliefs about its meaning, the artist and the place of the artwork in art history and larger societal issues, as well as individual expectations and goals. The affective elements are feelings evoked by the art piece such as pleasure, beauty, wonder, boredom, doom or surprise" (pp1-2).

These authors outlined four factors in aesthetic judgments (the first two are cognitive processes and the latter two are affective ones):

i) The importance of the perceiver's expectations.

ii) Expectations about the fluency of a stimulus (ie: the ease of processing). "For example, take a stimulus like an androgynous human face. Note that it can serve as an excellent prototype of a broad category (human beings), but also as an atypical example of narrow gender categories (male versus female). Indeed, when participants' task is simply to detect the presence of faces, the androgynous faces are fluent and liked. However, when participants' task is to categorise faces into male or female, the very same androgynous face becomes disfluent and disliked" (Yoo et al 2023 p5).

iii) The value placed upon the fluency of a stimulus - For example, if an individual wants to be surprised and/or uncertain, then fluency will be valued less. "For example, some people do not want to know the ending of a book from the beginning, they prefer a movie without a clear conclusion, they do not want to know the nature of love, and they appreciate an ambiguous artwork that remains puzzling over the years. An artist may prefer to

produce uncertain, disfluent works if their goal is to express indeterminacy, confusion, chaos or meaninglessness" (Yoo et al 2023 p7).

iv) The stimulus in relation to the goals of the perceiver - "For instance, if the painting shows people enjoying fruits of immoral activities such as cheating at cards, viewers with just-world beliefs might not appreciate learning about it even if the craft is superb... Similarly, prude viewers may dislike learning more about nudes..." (Yoo et al 2023 p8).

1.5.4. Specific Arts

Concentrating on music, Cheung et al (2023) stated: "Apart from extra-musical factors such as episodic memory or contextual associations, an important intra-musical factor by which music itself induces pleasure in the listener is via the confirmation, violation and delay of listeners' musical expectations" (p1). These researchers argued that "expectancy-driven musical pleasure results from two independent sources of expectancy: sensory expectations arising from acoustic information in the auditory signal itself, as well as cognitive expectations derived from learned relations between musical elements abstracted from the auditory signal. While sensory expectations form over relatively short timescales, cognitive expectations are acquired after extended exposure to multiple examples of a musical style" (p1).

One example of PP-based theory here is the "predictive coding of music" (PCM) model (eg: Friston 2010). "In PCM, musical expectations generated from higher-order brain regions (eg: prefrontal cortex) are thought to propagate downwards towards lower-level sensory regions (eg: the auditory cortex). The discrepancy between expected and actual incoming signals in sensory regions results in a prediction error or surprise. This error signal is propagated upwards along the cortical hierarchy to refine future expectations. The gain of the expectation is modulated by a precision estimate, or the inverse of uncertainty. Precision-weighted prediction error signals are thought to constitute reward for the listener to continue learning towards generating more accurate future expectations" (Cheung et al 2023 p2). Support comes from studies (eg: Cheung et al 2019) that found that ratings of pleasantness of chords and melodies were "jointly predicted by their surprise and uncertainty in listeners"

(Cheung et al 2023 p2).

Cheung et al (2023) performed similar research using thirty chord progressions sampled from commercially successful pop songs with two samples (25 adults (half musicians), and 39 adults). Ratings were taken of the surprise of each chord and the pleasantness.

More research has been undertaken on PP and music than visual art (Kesner 2023). But applying PP to the latter, Kesner (2023) talked of a "general pictorial competence" that probably evolved in hominins, which depends on "regularities in the physical features of the world" (p6). This leads to the development of prior expectations, which are crucial in "a successful encounter" with art. "Psychological research has long established that people prefer medium levels of sensory uncertainty, and, in the context of art perception, a medium stimulus complexity" (Kesner 2023 p7).

According to PP, the brain is "an engine of probabilistic hierarchical inference", and Kukkonen (2023) argued that this can applied to "our engagement with literary texts": "The notion of probabilistic hierarchical inferences seems to capture the way readers try to predict the verbal chain at different levels of abstraction, from sentences to characters' choices and mental lives, to plot developments and what is likely to happen in a given genre. Literary texts, for their part, seem to provide a designed sensory flow that is carefully crafted to sustain and engage readers' probabilistic inferences. They are 'probability designs': artefacts designed to ignite our inferential capacities with unexpected events (prediction errors), formulations that make the perspective from which the narrative is told salient (precision and attention), as well as signals for genres (such as 'crime fiction' or 'the modernist novel') that best allow readers to make overall predictions (precision expectations)" (pp1-2).

1.6. APPENDIX 1B - SOCIAL COMMUNICATION

"Social communication depends on the integration of sensory, emotional and cognitive information by a large network of brain regions. We employ and integrate vocal sounds, mouth movements, facial motions and hand/body gestures, when speaking to one another. During communication, we must retain and integrate these multiple auditory and visual cues in memory in order to

organise goal-directed behaviours. Thus, a communication circuit must include brain regions involved with perception, integration, memory and decision making regarding audiovisual information. The ventral frontal lobe, or inferior frontal gyrus, which includes Broca's area, has been an essential player in audio-visual speech perception and verbal working memory" (Romanski and Sharma 2023 p1).

Research on the "communication circuit" has involved non-human primates - for example, lesions of specific brain areas to establish function (eg: Goldman and Rosvold 1970), or recording of electrical activity in response to stimuli (eg: Diehl and Romanski 2014).

In terms of behaviour studies, Hwang and Romanski (2015) trained rhesus monkeys to watch an audio-visual movie clip, and then press a button if the following clip was different in any way. This is an audio-visual non-match-to-sample (NMTS) task, and it is a test of working memory primarily. It was found that "working memory performance accuracy was higher in trials where subjects had to detect a change to the visual face component, compared to trials when they detected a change to the auditory component in the non-match period, indicating better memory for the visual stimulus" (Romanski and Sharma 2023 p5).

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2. CHANGING MEMORIES

2.1. CREATING FALSE MEMORIES

Johnson et al (2023) began: "The science of the fallibility of memory has demonstrated that our childhood memories do not necessarily provide a veridical representation of flawlessly recorded events as they occurred. Rather, our recollection of past events is susceptible to errors and biases and can be fragmentary, contain incorrect details, and, oftentimes, be entirely fictional" (p1011).

The possibility of the creation of false memories is worrying. Wade et al (2002) showed this clearly in a classic experiment. Twenty participants (in New Zealand) were shown four pictures of their childhood events, of which one photograph had been doctored to show a fictitious hot air balloon ride. In three interview sessions the participants were asked to recall their memories of the pictures. "By the third interview session, half of the participants (n = 10) reported detailed, event-specific memories of the balloon ride, even though it was verified prior to the exposure that they had never experienced such an event" (Johnson et al 2023 p1011).

The researchers involved in this study provided replications (eg: Garry and Wade 2005; Strange et al 2008), but Johnson et al (2023) noted few independent replications, which motivated their research.

Twenty young adults were recruited in Norway. The same gender distribution as Wade et al (2002) (50% male), same age range, and inclusion criteria (eg: not studied psychology). The fictitious childhood event was changed to a Viking ship ride (more culturally relevant to the participants). Family members provided information about the childhood events.

Each participant provided photographs of themselves at events while four to eight years old. One of the photographs was doctored to show a Viking ship ride. Each participant completed three interview sessions over 1-2 weeks, during which they were encouraged to recall information about four photographs (three true and one altered). The interviews were transcribed, and three independent raters coded for false memories of the Viking

ship ride.

Around 90% of true event information was recalled (based on information from family members). in terms of the false event, "one participant reported clear false memories, three participants reported partial false memories during the first interview (20%), six participants were trying to recall, and 10 participants had no memory of the fictitious event. In Wade et al (2002), 7 of the 20 participants (35%) remembered the false event either partially or clearly during the first interview, of whom six participants reported partial false memories and one participant reported clear false memories" (Johnson et al 2023 p1014). In the third interview, eight participants (40%) recalled the false event partially or clearly compared to 50% in Wade et al (2002). Table 2.1 gives two examples of false memories.

- Fully-fledged false memories in first interview - "This boat gives me a weird feeling. I am a bit uncertain where this is. It must be a school trip in elementary school, second grade, I would guess when looking at the picture. The lifejacket looks familiar. [...] It looks cold... I don't remember anything else, just the feeling of being there, and the lifejacket that wasn't mine, but I borrowed it from someone" (p1015).

- Uncertain in first interview, but more definite in third interview - "I thought it was really cool to learn about Vikings, and to try – I remember that we had, let's call it a battle on a patch of gravel, and we had foam swords or something, and pretended to fight and dressed up and got to try a Viking helmet and stuff" (p1016).

Table 2.1 - Two examples of false memories in Johnson et al (2023).

The findings of Johnson et al (2023) provided a replication of Wade et al (2002). The former researchers stated: "The vivid imagery of detailed, event-specific information from a substantial percentage of the participants in the replication indicates that we successfully managed to modify the culturally appropriate and functionally equivalent false target event, similar to that of the original study. Also, the comparable findings of the 20-year-old original study and the current replication are astonishing, given that the replication was conducted at a time when people are much more familiar with and exposed to manipulated images and editing techniques" (Johnson et al 2023 p1017).

2.2. TARGETED MEMORY REACTIVATION

Hu et al (2020) began: "The idea of manipulating memories and thoughts during sleep is fascinating for neuroscientists, psychologists, and the general public. Although the idea may sound like science fiction, the past decade has witnessed an increasing number of studies wherein memory processing is directly manipulated during sleep. By covertly administering sensory cues while participants are asleep, associated memories from recent learning can be reactivated and modified" (p268). This process is known as "targeted memory reactivation" (TMR) (Paller and Oudiette 2022) [8].

"Memories continue to change, even after initial encoding and between episodes of deliberate rehearsal" (Hu et al 2020 p269).

The reactivation of stored information in memory during sleep aids consolidation of that information. Rats who have learned a new maze before sleep show the same pattern of neural activation during sleep as during that learning, for example (Wilson and McNaughton 1994).

Preferential sleep consolidation could aid which memories are consolidated. Rasch et al (2007) is seen as the first experiment to show TMR in humans by using olfactory cues. During learning specific odours were presented, and during post-learning sleep, the same odours were released. Recall of learning improved for the material associated with the odours presented during sleep compared to non-exposed material.

Rudoy et al (2009), and Anthony et al (2012) used auditory cues associated with learning in experiments with humans. Oudiette et al (2013) developed this work, and established the potential of TMR.

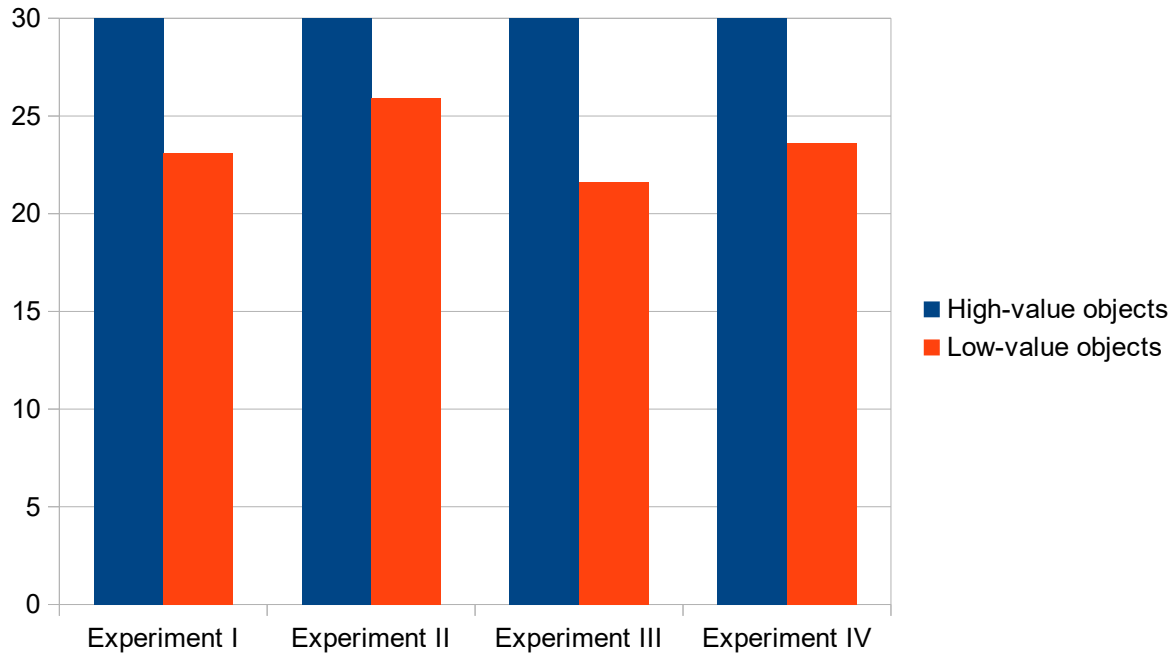
Sixty participants over four experiments were instructed to remember the unique locations of 72 objects on a computer screen. When an object was presented, an associated sound was played (eg: "dog" and "woof"). Half the objects were allocated low reward values in terms of recall and half high reward values. After learning, participants were allowed to sleep for ninety minutes in a darkened room.

In Experiment I, no object sounds were played during sleep, while in Experiment II 18 sounds associated with low-value objects were played in the middle of sleep. Experiments III and IV involved no sleep after learning, either watching a movie (with no object sounds played) in the former or solving difficult mental tasks (but the sounds were played during this time) in the latter. The

[8] The term "TMR" is attributed to Oudiette and Paller (2013) originally.

outcome measure (or dependent variable) was a memory task where the 72 objects were presented individually in the centre of the computer screen and the participants had to move it to its specific location.

Across all four experiments, more high-value than low-value objects were correctly recalled. This fits with the view that "important information tends to be replayed, and replay tends to forestall forgetting" (Oudiette et al 2013 p6673). More low-value objects were recalled in Experiment II (auditory cues during sleep) than Experiment I (sleep only). The lowest recall of low-value objects occurred in Experiments III and IV (awake) (figure 2.1).



(Data from Oudiette et al 2013 table 1 p6674)

Figure 2.1 - Mean correct recall of objects in four experiments.

TMR research has grown in popularity in the 2010s, and experiments have investigated different sorts of learning (eg: word association; spatial memory; grammar learning). Another variable in the experiments is the use of within-participant (or repeated/related) design (ie: TMR and non-TMR conditions both experienced by each participant) or between-participant (or independent) design (ie: different participants in the TMR and non-TMR conditions). Studies further vary in when the TMR occurs

during sleep (eg: rapid eye movement (REM) or non-REM (NREM) (Hu et al 2020).

Hu et al (2020) performed a meta-analysis of 91 TMR experiments (in seventy-three articles). The following key conclusions were drawn:

i) Overall sleep TMR was more effective than no TMR in terms of post-sleep recall of learning prior to sleep.

ii) TMR during stages 2 and 3 NREM sleep was effective, but not during REM sleep nor waking.

iii) Different forms of memory and recall were improved by TMR.

Hu et al (2020) ended: "Despite some inconsistent results from single studies, meta-analytical results provide compelling evidence that applying sensory cues during NREM sleep can reactivate associated memories and promote memory consolidation. TMR effects are found across a range of learning domains, including but not limited to declarative memory and skill learning" (p239).

Table 2.2 outlines some of the key methodological differences between the studies in the meta-analysis.

Hu et al (2020) noted these general issues:

a) That "some tasks placed in one learning category may engage processing that depends on multiple memory systems operative concurrently. For example, artificial grammar learning and other types of statistical learning may involve both implicit learning and declarative memory" (Hu et al 2020 p238).

b) Whether the learning is new (eg: nonsense syllables) or familiar (eg: everyday words). "The effectiveness of TMR is generally contingent on prior learning and associations made with specific cue stimuli" (Hu et al 2020 p238).

c) Explaining TMR - eg: the neural mechanisms involved. "Cueing may simply bias spontaneous reactivation..., but there may be important differences. Because neural signals that completely and unequivocally indicate memory reactivation during sleep have not yet been established, this question remains open" (Hu et al 2020 p239).

d) Whether TMR improves the memory for cued

information, but harms other recent learning. "That is, memory storage may normally involve competition, such that enhanced storage of some information would be expected to have repercussions" (Hu et al 2020 p239).

e) Almost all studies were laboratory-based experiments. Goldi and Rasch (2019) was an exception that investigated TMR for vocabulary learning while sleeping at home.

- Length of learning, sleep (eg: less than 1 hour to 8 hours), and retention periods.
- Activity during waking condition.
- Time of experiment during the day/night cycle.
- Type of TMR - olfactory; auditory-non-verbal (ie: sounds); auditory-verbal (ie: spoken words).
- Between-participant or within-participant design.
- Type of memory studied.
- Sample size and make-up (eg: age range of 13 to 71 years old).
- Stages of sleep when TMR administered.
- Outcome measure - eg: correct recall; errors; false memories; recognition; performance of skill.

Table 2.2 - Key methodological differences between studies of TMR.

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3. THINKING ABOUT POSSIBILITIES

3.1. INTRODUCTION

Humans are able to think about possibilities. "We can all form theories about how an effect might have been produced, even if we were not there to witness the actual cause ourselves. And we can all imagine and compare a multitude of possible ways the future might turn out, or speculate about once possible ways the past might have turned out but did not" (Redshaw and Ganea 2022 pp1-2).

While Comrie et al (2022) began: "The ability to imagine is essential to human experience. At a broad level, imagination has a major role in human creativity, agency and everyday thoughts and actions. More specifically, humans have and express many types of imagined experiences. These include recollections, predictions, simulations, counter-factuals, fantasies, suppositions and mind-wandering — and, in pathological cases, hallucinations and confabulations. These wide-ranging forms of imagination are relevant, if not essential, to a similarly wide range of cognitive domains, such as memory, planning, learning and inference" (p1). However, these authors admitted that "our understanding of how imagination is realised as a biological process in the brain remains nascent" (Comrie et al 2022 p1).

Redshaw and Ganea (2022) outlined the different ways of studying thinking about possibilities (TAP) and the different issues:

- Neurophysiological basis.
- Development of TAP in childhood.
- Cultural differences.

- Advantages of TAP in terms of learning, and decision-making.
- Non-human animals.
- The evolution of TAP in humans.

3.2. NEUROPHYSIOLOGICAL BASIS

The "fundamental ability to generate possibilities that do not correspond to the actual present" (pp1-2), Comrie et al (2022) called "generativity". Researchers have tried to understand the neurobiology of such a process by distinguishing "actual from imagined experience, specific neural processes in the healthy brain must 'parse' internal representations as ongoing experience (actual) versus internally generated alternative experience (imagined)" (Comrie et al 2022 p2).

Comrie et al (2022) reviewed the evidence based around five questions:

a) Where in the brain does generativity occur? The answer seems to be the hippocampus. One line of evidence is brain-injured human patients, like "HM". He had part of the hippocampus area surgically removed to deal with severe epilepsy, and was subsequently found to have problems in future-oriented thinking and constructing fictional events (eg: Klein 2002). Neuroimaging studies have provided more evidence, showing activation of the hippocampus during imagining tasks (eg: Addis and Schacter 2011).

b) How to identify generative neural activity? Rodent studies are particularly relevant here. Electrodes can be attached to the brain which record neural activity during movement through a maze. "Place cells" in the hippocampus fire at particular places in the maze to suggest actual perception (appendix 3A). But there is evidence of place cells firing when a rat is not at that particular place, and "these moments can be provisionally understood as times in which a representation of the place field location is internally generated, even though the animal actually occupies a different location at that moment" (Comrie et al 2022 p3) (eg: Pavlides and Wilson 1989).

c) What brain patterns correlate with generativity? Using rodents also, studies have found a pattern of hippocampal cell activity during sleep after a day spent

running a new maze. "Firing sequences of place cells that were active during running on a maze were found to reactivate in similar sequential order during subsequent sleep, as if briefly 'replaying' past spatial experience" (Comrie et al 2022 p4) (eg: Nadsady et al 1999).

But the pattern of firing can be more than a simple replay, suggesting "an abstract internal spatial model of the encountered environment, or a spatial 'cognitive map'. For instance, replays can be biased toward paths that are less behaviourally traversed, and replays can be consistent with random trajectories through a familiar space; replays like these may sample locations that are not the most behaviourally salient or the most physically occupied to support the maintenance of a flexible model of the environment, and this function could help explain why replays are inconsistent with a rigid recapitulation that passively records recent experience. These reports suggest that replay, instead of directly reinstating specific episodes, may abstractly reflect past experience via an internal spatial map" (Comrie et al 2022 pp4-5).

Place cell firing patterns have been recorded before starting a maze which suggests an anticipation of future events (Comrie et al 2022).

d) How the brain organises actual versus generative patterns? There is evidence of organisation of cells in the rodent hippocampus that distinguishes "actual present" from imagined, but the latter sub-divides into "experienced past", "anticipated future", and "possibilities" (Comrie et al 2022).

e) What is the role of generativity in cognition? One theory is that "the hippocampus is a system for 'relational' memory: a system for inferring abstract relationships between observable events (such as sensory stimuli, actions and internal states). Integrating information in relational memory is beneficial in that it enables inference and generalisation to novel circumstances, such as those where elements of previous experience are reconfigured. This can be advantageous regardless of whether those novel circumstances can be anticipated at the time of generating the relational information, consistent with the idea that generative activity can but does not always relate to immediate behaviour" (Comrie et al 2022 p10).

Neuroimaging has also shown that particularly areas of the brain's "default mode network" (DMN) [9] are active

[9] This includes the medial prefrontal cortex, anterior cingulate cortex, lateral and medial temporal

during counter-factual thinking (ie: imagining alternatives). Khoudary et al (2022), for example, asked 32 participants to imagine that negative past personal experiences turned out better, "either by envisioning that they had taken an alternative course of action or by envisioning that the contextual circumstances surrounding the event had been otherwise" (Redshaw and Ganea 2022 p2).

Redshaw and Ganea (2022) explained: "Distinct regions beyond the DMN, however, were differentially activated depending on the type of counter-factual imagined. Overall, this finding suggests that the human brain does not support an encapsulated, one-size-fits-all approach to imagining possibilities, and instead this capacity draws on a range of interlinked and differentially engaged neurocognitive components" (p2).

This was a study of "episodic counter-factual thinking" (eCFT) (De Brigard and Parikh 2019), which can be envisaged this way: "We may imagine having answered an important phone call we actually missed, or maybe having said something we actually never did" (Khoudary et al 2022 p1).

Similar neural activity in the DMN was reported by Addis et al (2009) during episodic memory retrieval, episodic future thoughts, and eCFT. However, there are also different brain areas used in each case, and there are differences based on the type of eCFT, as Khoudary et al (2022) showed. This study distinguished between internal and external eCFT. The former is encapsulated in the phrase, "if only I had done something different", and the latter is "if only the environment had been different". For example, getting sunburnt on the beach: "Thinking back, you may consider having done something different: 'If only I had applied sunscreen before going to the beach!'. Alternatively, you could imagine that something about the situation itself had been different to prevent the negative outcome from happening: 'If only it had been cloudier that morning!'" (Khoudary et al 2022 p2).

Specifically Khoudary et al (2022) found: "Both internal and external eCFT engaged midline regions of cingulate cortex, a central node of the DMN. Most activity differentiating eCFT, however, occurred outside the DMN. External eCFT engaged cuneus, angular gyrus and precuneus, whereas internal eCFT engaged posterior cingulate and precentral gyrus" (p1).

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lobes (including hippocampus), inferior parietal lobule, and caudate (Khoudary et al 2022).

3.3. DEVELOPMENT OF TAP IN CHILDHOOD

The early origins of TAP have been investigated with four years old being a cut-off point in such studies (ie: unable to show TAP younger than that; eg: Redshaw and Suddendorf 2016). While, Cesana-Arlotti et al (2022) (table 3.1), for example, suggested that fourteen month-olds could "simultaneously represent two mutually exclusive possibilities" (Redshaw and Ganea 2022 p3), though behavioural and physiological measures have to be used.

Another method used with 12 month-olds was the presentation of four balls on a screen (three yellow and one blue, say), which disappeared one at a time (eg: Teglas et al 2007). This was used to test probabilistic intuitions. It was found that "12-month-olds look longer at a less probable result (the blue ball exiting) than at a more probable one (a yellow ball exiting). Infants seem to expect the more probable outcome..." (Cesana-Arlotti et al 2022 p7).

Redshaw and Suddendorf (2016) used an upside-down Y-shaped tube and dropped a ball in at the top. It could fall out in one of two possible directions, and the children had to catch it. "Strikingly, only four-year-olds prepared the optimal action reliably and spontaneously (simultaneously reaching for both exits with their hands). Instead, younger children and apes failed to do so, suggesting that they could not optimally prepare for two mutually exclusive outcomes. Interestingly, turning the task into a social game did not improve performance, and the challenge children may face seems not to be simply one of manual co-ordination" (Cesana-Arlotti et al 2022 p2).

The contradictory findings may be a product of the methodological difficulties of testing young children, and that the different studies were testing slightly different aspects of TAP. For example, commenting on Redshaw and Suddendorf (2016), Cesana-Arlotti et al (2022) argued that failure in the task of catching the ball could be due to an inability to represent two mutually exclusive possibilities at once or "may reflect their limitations in decision-making when facing uncertain events" (p2) [10].

[10] This task has been used with captive chimpanzees who failed to cover both exits. However, critics argued that chimpanzees did not cover both exits because the behaviour was not natural to them (Ly 2023). Engelmann et al (2023) adapted the experiment to behaviour that wild chimpanzees were familiar with - namely, a platform containing food that would become unstable and the food would be lost. In the control condition when a rock was dropped on the platform it was obvious which side to hold to stop the food being lost. In the experimental condition (with the equivalent of the Y-shaped tube), it was not clear which side of the platform to hold, but thirteen of fifteen chimpanzees tested

- Cesana-Arlotti et al (2022) used infants' pupil dilation as the measure of the ability to represent multiple possibilities. Ten and 14 month-olds were presented with three objects (a puppet, a toy elephant, and a ball) before they were hidden behind screens (the puppet and the ball behind one screen and the toy elephant behind its own screen). Then one of the three objects was partially revealed in such a way that it showed the common feature to all three objects. In the 1-possibility condition (control) the object emerged from the screen hiding one object, while in the 2-possibility condition, the object came from behind the two-object screen.

- Cesana-Arlotti et al (2022) explained the logic behind the use of the pupil dilation measure: "Just as adults' pupil diameter grows monotonically with the amount of information held in memory, we expected that infants' pupil size would increase with the number of alternatives sustained in memory as candidate identities for the partially occluded object" (p1).

- For 14 month-olds only, "their pupils increased more at the appearance of the partially occluded object when there were two possible identities" (Cesana-Arlotti et al 2022 p7). This was taken as evidence that the infants could hold two possibilities in their mind at once.

Table 3.1 - Cesana-Arlotti et al (2022).

Using pretend play and imagination as evidence, Harris (2022) argued that 2-3 year-olds "can imagine and draw appropriate inferences about possible events and situations" (Redshaw and Ganea 2022 p3).

During pretend play young children show evidence of enacting spatial displacements (eg: pouring tea from an empty teapot), for instance. This has been shown in experiments with two year-olds by Harris and Kavanagh (1993). "For example, having watched a play partner 'pour' make-believe tea over one of two pigs and been prompted to 'dry the pig who's all wet', they used a towel to wipe the appropriate pig, even though neither pig was actually wet" (Harris 2022 p2).

This was Experiment 5 by Harris and Kavanagh (1993), while in Experiment 6 2-3 year-olds were asked about the imagined events. "Having watched Teddy, a mischievous hand puppet, enact various transgressions (eg: 'pour' pretend tea from an empty teapot over the head of a toy monkey), they replied appropriately to an adult's questions about what had happened. When asked what had been displaced (What did Teddy put on the monkey's head?) and about the resultant state of Teddy's victim (Is the monkey's head wet or dry?), the majority of both younger

were more likely to hold both sides (Ly 2023).

(24–30 months) and older (25–36 months) children replied correctly (ie: 'tea' and 'wet')" (Harris 2022 p2).

Wente et al (2022) investigated pretend play and counter-factual thinking in an experiment with 62 three and four year-old Peruvian children, and fifty-seven US children from low-income households. The experimental design was based on Buchsbaum et al (2012), and involved a "zando" machine. This is a wooden box with a doorbell inside that plays "Happy Birthday" if the correct block ("zando" vs "non-zando") is placed in the box. Child learned the causal relationship that the zando block led to the tune playing.

Then the children were asked counter-factual questions (eg: "If this one (while pointing to the zando) was not a zando, what would happen when we put it on the machine?"; p5). This was the control condition of the experiment. In the subsequent condition, the machine was taken away and the children were given wooden blocks. They were encouraged to pretend that the blocks were the zando machine, and asked the same counter-factual questions (pretend play condition).

Both groups of children were able to answer the counter-factual questions correctly significantly above chance in the pretend play condition, but not in the control condition.

Buchsbaum et al (2012), using sixty US children from mixed-income households of the same age, had found that both conditions were answered correctly above chance. Wente et al's (2022) study showed both socio-economic status/income, and cultural differences in understanding counter-factual reasoning in young children.

Gautam et al (2022) concentrated on regret. They stated: "Regret is an emotion that arises when we compare what is happening in the present to what would be happening had an alternative course of events taken place in the past. For example, when caught in a downpour you might feel regret if you realise that you did not pack an umbrella in the morning. Regret thus presupposes a capacity for counter-factual thinking: reflecting on a past event and understanding that there were once other ways that event might have turned out. Regret has important functions, such as helping us learn to behave more adaptively when confronted with similar situations with multiple possible outcomes in the future. In fact, evidence suggests that adults explicitly identify regret as the most beneficial negative emotion, in terms of both learning from past mistakes and making better future

choices" (Gautam et al 2022 p1).

What about children? The "two boxes task" is commonly used to study it. A child is presented with a choice of two boxes containing prizes, and must choose one. It contains a small prize (eg: a sticker) and child is asked how they feel. Then they are shown the prize in the unchosen box (which is always better) (eg: a toy), and asked how they feel now. Six year-olds show evidence of negative emotions after seeing the non-chosen prize (eg: Amsel and Smalley 2000).

Some researchers interpret this emotion as regret, but Gautam et al (2022) were not convinced: "After all, the children, upon seeing the alternative prize, may simply feel another negative emotion, such as frustration (eg: 'Oh no! I want that other prize!'), without considering and mentally undoing their past choice (ie: 'Oh no! I wish I had chosen differently!'). Therefore, it is unclear if children in such tasks are genuinely experiencing the counter-factual emotion of regret" (p2).

Gautam et al (2022) added different conditions to their version of the two boxes task. One hundred and sixty 4-9 year-olds were allocated to one of four conditions when faced with two wooden boxes containing prizes (one or five stickers):

1. "Better-outcome-possible" condition - Children chose between the boxes, but always received the lesser prize. This should produce counter-factual regret when shown the better prize in the non-chosen box.

2. "Better-outcome-impossible" condition - The children were forced to choose one box which contained the one sticker. This should not produce counter-factual regret as there was no genuine choice.

3. "Worse-outcome-possible" condition - The same as (1) but the children always got the better prize. This should produce a feeling of relief after seeing the prize in the other box.

4. "Worse-outcome-impossible" condition - A mirror of (2) but with the better prize.

After the choice, the mean emotion rating was six on a seven-point scale in all conditions. The rating offered after seeing the alternative prize was "happier", "sadder", or "the same". Children were sadder in the better-outcome conditions, and happier in the worse-outcome conditions. "Results showed that children in the

better-outcome-possible condition were significantly more likely than those in the better-outcome-impossible condition to report feeling sadder when the better prize was revealed..., consistent with the notion that children were genuinely experiencing the counter-factual emotion of regret in the former condition" (Gautam et al 2022 p5). There was no difference found based on age, which was unexpected.

There was no evidence of counter-factual relief in the worst-outcome conditions.

More sophisticated abilities related to TAP develop later in childhood, and may be linked to language development. The evidence is divided about possibility reasoning (or modal cognition) (eg: "if I do X, Y will happen"). In the debate, "findings from studies with infants and non-human animals are interpreted as evidence for successful logical reasoning in the absence of language, while findings from studies with pre-schoolers point to persistent difficulties" (Grigoroglou and Ganea 2022 pp1-2).

For example, children are shown two containers, of which one holds an unseen reward. The experimenter shows that the reward is not in container A, say, and then asks the child to find the reward. Pre-linguistic children and non-linguistic animals choose container B (eg: Call and Carpenter 2001). This would suggest an understanding of the logical reasoning "not A, therefore B". However, this is not necessarily the case. "For instance, when shown that one of two locations is empty, children may engage in an 'avoid empty' strategy and search in the alternative location not because they have reached the logical conclusion that the reward necessarily has to be in the alternative location but because it is the only salient hiding location (after avoiding the empty location)" (Grigoroglou and Ganea 2022 p3).

Mody and Carey (2016) created a more sophisticated version of the task with four containers, but the reward could by in A or B, say. Children were shown that container A was empty, for instance. The use of logical reasoning would lead to choosing B, but the "avoid empty" strategy would mean choosing B, C or D. Three year-olds and above chose B significantly above chance, but younger children did not (Grigoroglou and Ganea 2022).

Grigoroglou and Ganea (2022) linked the development of possibility reasoning with the acquisition and use of possibility terms (eg: maybe, possibly, probably, might, could be). Basic abilities appear at three years old, but a "mature understanding" later (eg: seven years old)

(Grigoroglou and Ganea 2022).

Grigoroglou and Ganea (2022) concluded that "children's conceptual understanding of logical and modal concepts seems to go hand in hand with children's linguistic understanding of logical and modal terms. However, evidence from children's production shows that such terms tend to appear in speech earlier than the age children comprehend these terms and before they show evidence for mature logical and modal reasoning" (p7).

"People often speculate about what the future holds. They wonder what will happen tomorrow, and what the world will be like in the distant future. Nonetheless, people's ability to consider future possibilities may be restricted when they consider their own futures. Adults show the 'end of history' illusion, believing they have changed more in the past than they will in the future" (Goulding et al 2022 p1). This is a deficit in TAP here linked to being anchored in the present (Goulding et al 2022).

Goulding et al (2022) investigated this behaviour with three year-olds in Canada. The children were offered pairs of objects - one appropriate to a child or baby, the other an adult (eg: toy vs wrist-watch). They were asked which they preferred now, in the past as a baby, and in the future as an adult. The children were better at imagining their preference in the future if they had not been reminded of the present preference - ie: "when they are not confronted with things that anchor them to the present" (Goulding et al 2022 p7).

The researchers drew the conclusion that "children's difficulties with mental time travel reflect a failure to shift away from the present rather than an inability to simulate alternative possibilities" (Goulding et al 2022 p1). However, the researchers did accept that the explanations are not necessarily mutually exclusive.

3.4. CULTURAL DIFFERENCES

Human cultural practices can enhance TAP; for example, "cultural time-keeping methods such as oral or physical calendars can allow us to mentally generate and communicate about possibilities that might take place at precise and agreed upon moments in the future" (Redshaw and Ganea 2022 p4).

Vale et al (2023) preferred the term "prospective cognition", and reflected on its link to culture. Culture involves many behaviours that have future benefits,

including food preservation, avoiding certain toxic foods, and "healthy habits".

Prospective cognition (or prospection), according to Szpunar et al (2014), involves "several modes of future-oriented thought including planning (pre-empted steps to meet a goal), prediction (estimated likelihoods), simulation (mental representations of the future), and intention (mental act of goal setting). Each of these modes can include content that is episodic (relating to a specific personal experience), semantic (relating to general knowledge of the environment) or a mixture of both" (Vale et al 2023 pp2-3).

A two-way relationship between prospective cognition and culture can be described. Prospective cognition allows culture to develop the behaviours for the future benefits, but culture gives the opportunity for prospective cognition. "At the most basic, of course, culture allows the time and space to develop future goals. Routine tasks, such as planning routes to work, involve many cumulative inventions across generations that yielded pathways, trains, buses and cars. In many cases, the advent of these cultural products (eg: agriculture and institutions that trade in consumables) alleviate present motivations, such as the need to forage or to cultivate produce. With basic needs met, a shift towards prospective cognition and the pursuit of goals in the distant future can occur, spurring modes of future thought" (Vale et al 2023 p7).

Cultural influences may also bias and limit TAP. For example, Epstude et al (2022) asked highly partisan Democrat and Republican voters in the USA to think of alternative scenarios during the time of the Trump or Biden presidency. Participants were better at the counter-factual thinking if it aligned with their political views (appendix 3B).

3.5. ADVANTAGES OF TAP

In terms of decision-making, TAP is involved in the situation like the offer of "£5 now or £10 in one week". Previous research has suggested that delaying the reward was a self-control issue, but Bulley et al (2022) (table 3.2), for instance, found the value placed on the reward-time combination was more important (eg: subjective value of anticipating the pleasure of a future reward).

- Study - Choosing to delay gratification for larger, later (LL) rewards compared to smaller, sooner (SS) rewards (inter-temporal choice task).

- Participants - 117 adults (mostly in USA) recruited online.

- Task - "Monetary Choice Questionnaire": varying choices of SS vs LL US dollar rewards (eg: $18 today or $25 in nineteen days). After each choice, there was a rating of the confidence of the decision as the right one.

- Comment - If the choice of a LL reward was a sign of self-control, then participants should be more confident about this decision compared to a SS reward choice. This was not found. The confidence level varied with the length of time, and the size of the SS compared to the LL rewards. The researchers took such findings as evidence of decision-making based on subjective valuation of the options. Bulley et al (2022) did not reject self-control completely in delaying of gratification choices, simply that it is one factor in such decisions. As they stated: "simply interpreting choices of LL reward as a capacity for self-control is problematic" (p8)... "Our findings challenge self-control views and instead cast inter-temporal choice as a form of value-based decision-making about future possibilities" (Bulley et al 2022 p1).

Table 3.2 - Bulley et al (2022).

Causal judgments involve the attribution of event A causing event B, say. There are two possible ways that causal judgments are made, according to Gerstenberg (2022) (who favoured the first in the the "counter-factual simulation model"; Gerstenberg et al 2021) - counter-factual simulation or hypothetical simulation. "A counter-factual simulation involves observing what actually happened, mentally travelling back in time to imagine a change to what actually happened, and then simulating how this alternative possibility would have played out. If the outcome in the counter-factual situation would have been different from what actually happened then the event of interest caused the outcome. By contrast, a hypothetical simulation involves imagining a possible future. This does not require going back in time and mentally changing something that already happened" (Gerstenberg 2022 p1).

TAP includes an element of "moral judgments of 'permissibility', like whether an agent 'ought' or 'should' do something" (Acierno et al 2022 p1). These moral judgments form "implicit or default (rather than deliberative) representations of what is possible" (Acierno et al 2022 p1).

Reasoning is often called "modal" thought, and it is connected to moral thought. "For example, people's judgements of morality influence their perceptions of the relevance of alternative possibilities, such that they think it is more relevant to consider morally good possibilities than morally bad ones. Moreover, prior work by Shtulman & Tong [2013], found that the more frequently participants judge extraordinary events as possible, the more often they judge extraordinary actions as permissible" (Acierno et al 2022 p2).

How quickly a decision must be made is also important, and Acierno et al (2022) factored this variable into their study. US adults were recruited via "Amazon Mechanical Turk" or "Prolific", and they were presented with the scenario of a cake containing nuts baked for a children's party, but at the very last moment it is discovered that one of the children has a nut allergy. Options of what to do were offered, which were "ordinary" (eg: serve another food instead), "impossible" (eg: "zap the nuts from the cake"), "immoral" (eg: "lie that the cake is nut-free"), "improbable" (eg: find a nut-free cake at hand), and "irrational" (eg: postpone the party for one month). Time to respond was varied (slow or fast). In total, varying the options, there were over 100 000 moral judgments by around one thousand participants.

Acierno et al (2022) summed up the findings: "When making moral permissibility judgements quickly, participants were more likely to judge that improbable, irrational and impossible actions were not permissible, indicating that default representations of permissibility may be reflecting default representations of possibility" (p1). The study supported a connection between modal and moral thought.

Fitzgibbon and Murayama (2022) described the concept of "counter-factual curiosity" - the motivation to seek out "information about what might have been had past events been different" (p2). Such a behaviour can lead to negative experiences (eg: regret), but Fitzgibbon and Murayama (2022) argued that "it is motivated by the potential use of counter-factual information for adaptive decision making (its long-term instrumental value) and the drive to reduce uncertainty" (p2) (eg: "Functional Theory of Counter-factual Thinking"; Epstude and Roese 2008).

There are two types of the behaviour - "spontaneous counter-factual thoughts" (ie: thinking about alternatives), and seeking out counter-factual

information. The former is seen in an experiment where participants were asked to think aloud while playing a card game (Markman et al 1993). Nearly all participants had spontaneous thoughts like, "If I had gotten the king, I would've lost to the dealer" (quoted in Fitzgibbon and Murayama 2022).

Another example is Davis et al's (1995) study of individuals who had experienced traumatic life events (eg: sudden death of an infant). "The majority of respondents (76%) reported mentally undoing the event in the weeks after an infant's death, and almost half reported still thinking 'if only...' thoughts years after the event" (Fitzgibbon and Murayama 2022 p2).

In terms of seeking out information about counter-factual alternatives, research has found the behaviour by adults, children, and non-human primates. The use of vignettes is a common method of study with humans. For example, Shani and Zeelenberg (2007) "asked participants whether they would want to know the outcome of a lottery for which they had lost their ticket (but remembered the numbers). Participants were more likely to want to know when there was a high likelihood that they had had the winning numbers than when there was a low likelihood, suggesting that their curiosity was sufficient to overcome the potential regret of not returning the ticket" (Fitzgibbon and Murayama 2022 p2).

An example with children is Fitzgibbon et al's (2019) card game with four and five year-olds who had the opportunity to use "magic glasses" to peak at an unseen card after a choice. Three-quarters of the children chose to know, and more so after a negative decision (Fitzgibbon and Murayama 2022).

Rhesus macaques have been studied among non-human primates. For example, in a study by Wang and Hayden (2019), "macaques made choices between probabilistic gambles for water rewards. Importantly, choosing one of the gambles would additionally lead to information about the outcome of the unchosen gamble. The macaques chose the informative gamble more often than would be expected by chance, even foregoing water rewards to do so: they chose the informative gamble even when the chance of reward (expected value) was lower, suggesting that the information itself had some value" (Fitzgibbon and Murayama 2022 p3).

3.6. NON-HUMAN ANIMALS

Delay of gratification shows the ability to imagine

the future, and it is also a sign of self-control. "Self-control is cognitively challenging as individuals must not only resist temptation in the present moment but also override the tendency to temporally discount or devalue future rewards" (Schnell et al 2022 p1). Is there an association between self-control and other cognitive abilities related to intelligence?

In humans, children who resist temptation on the "marshmallow test" (ie: one marshmallow now or two in a few minutes) (Mischel et al 1989) subsequently do better in academic tests (Schnell et al 2022).

Among chimpanzees, greater self-control is associated with better performance on thirteen different cognitive tasks (Beran and Hopkins 2018). This relationship has been observed in other species, like corvids (crow family).

There is a logic that these birds should show such behaviours, as Schnell et al (2022) explained: "In corvids, caching behaviour, ie: hiding food for later consumption, offers an illustrative example of how ecological pressures such as the need to inhibit immediate gratification to plan for future meals may have driven the evolution of self-control. Caching behaviour also imposes social pressures that might have reinforced the evolution of self-control. For instance, some species of corvids such as crows, ravens and jays, are vulnerable to cache theft. These species use strategies that require self-control to minimise the chance of conspecifics stealing their caches, such as waiting for the optimal moment to make a cache, ie: when a competitor is out of sight or out of earshot" (p2).

Schnell et al (2022) tested ten Eurasian jays in two experiments. The first experiment measured various cognitive abilities, including spatial memory. In the second experiment the birds were taught that different drawers containing food would be pushed open by an experimenter. Delay of gratification was tested by pushing open first the drawer with less preferred food and then it was closed, and the second drawer containing more preferred food was opened. The time to wait was varied. The second drawer did not open if the food was taken from the first drawer. The ability to wait was found to positively correlate with scores on the cognitive tests in the first experiment.

3.7. EVOLUTION OF TAP IN HUMANS

The evolution of TAP in humans must mean that the

ability was evident in human ancestors. The only evidence here is archaeological (Langley and Suddendorf 2022). Redshaw and Ganea (2022) summed up: "By around 1.8 Ma [million years ago], for instance, Homo erectus individuals were manufacturing stone tools and transporting raw materials across vast distances, presumably because they recognised the possibility of using these tools and raw materials in the future. Later, around 500 000 years ago, Homo heidelbergensis individuals began assembling compound tools and apparently co-ordinating their actions in the service of shared goals — activities likely underpinned by an ability to reason through several interconnected steps in a possible causal chain. Only by around 100 000 years ago, however, is there compelling evidence of Homo sapiens and Neanderthals burying their dead, potentially reflecting sophisticated thoughts about the abstract possibility of an afterlife" (pp6-7).

Imagining what is needed in the future leads to planning and preparation. Searching for evidence of these behaviours is the basis of archaeological research into TAP.

Control of fire is one indicator of foresight. "Making fire requires considerable planning and persistence. Whether using firesticks or striking stones, resulting embers or sparks need to be carefully caught and fanned into a flame, requiring fire-feeding materials to be at the ready. Maintenance of fire also requires ongoing attention, particularly if certain temperatures are required for cooking or tool-making. While there are glimmers of evidence for controlled use of fire reaching back some 1.6 Ma, habitual use of fire (systematically repeated use of fire in specific sites and/or regions) is only evident from about 400 000 to 300 000 years ago" (Langley and Suddendorf 2022 p2).

Analysis of stone technology is another area of research. For example, the amount of time involved in making such tools requires the ability to imagine their future usefulness. Early evidence of foresight here 1.8 Ma, including the movement of materials across landscapes in preparation (Langley and Suddendorf 2022).

Hunting, particularly dangerous or difficult-to-catch prey, shows planning. "For example, when hunting large and/or dangerous animals, modern hunter–gatherers typically first observe the animal to learn its behavioural patterns (such as what path it takes to waterholes or rivers), before they plan the attack and prepare accordingly (which might include prepping

weapons, recruiting other hunters, digging a pit-fall or building a corral)" (Langley and Suddendorf 2022 p4). Direct evidence of technology use here around 500 000 years ago (Langley and Suddendorf 2022).

A variety of other technologies and artefacts signal thought about the future, including watercraft, semi-permanent forms of ornaments, and maps or hunting plans engraved on cave walls (Langley and Suddendorf 2022).

Langley and Suddendorf (2022) ended: "Despite the vagaries of the archaeological record, it appears that the origins for the human ability for thinking about future possibilities stretches back beyond 1.8 Ma. From this early period of humanity, up through an increasingly complex family tree, the ability to conceive of the future and act to mitigate its risks or maximise a potential outcome developed gradually. These abilities cumulated in both individuals and groups co-operating on an ever-increasing scale and co-opting in increasing types of material culture to manipulate and track the future. People eventually exchanged ideas about potential situations, driving them on to avoid some possibilities while striving to turn others into reality" p8).

3.8. FUTURE SELF

Parfit (1971) suggested that "the sense of 'connection' that individuals feel to distant, future selves may feel weak, and substantially weaker with greater periods of time, to the point that some very distant future selves may feel like different people altogether — and even, strangers" (Hershfield 2019 p72).

But Hershfield (2023) argued that "people who feel close to their future selves - and realise they may be different to their present selves - make better decisions" (Frankel 2023 p46).

There is support for the perception of the future self as similar to another person. For example, undergraduates were asked to make decisions for the future self, the current self, and a classmate (Pronin et al 2008). The participants "made decisions for their future selves that were more on par with the decisions that they made for their classmates rather than for themselves (eg: by signing their future selves up for a similar amount of volunteer work as they assigned to others)" (Hershfield 2019 p72).

Feeling a greater connection to the future self influences decisions made now (eg: save more in a financial game; Bartels and Rips 2010).

Combining both a sense of connection and viewing the future self as another person has been studied (eg: Bryan and Hershfield 2012). University employees were asked to think about saving for retirement, but the message was presented in different ways - as a responsibility to the future self (self as other person condition), or in their best self-interest (self as same person condition). The former framing produced more changes to actual saving behaviour (Hershfield 2019).

But Zimbardo and Boyd (2008) suggested that being too focused on the future leads to less willingness to help others (Frankel 2023).

3.9. APPENDIX 3A - PLACE CELLS

The original work on rats and recording of electrical activity as they moved around, which led to the discovery of "place cells" was performed by O'Keefe and Dostrovsky (1971). Subsequently, work with rats found other cells that responded to specific spatial positions (eg: "grid cells"; detailed in Moser et al 2008). Doeller et al (2010) reported evidence of such cells active in humans "moving" in virtual mazes.

The idea of specific cells firing has been expanded to include "time cells" (details in Eichenbaum 2014), which fire as a means to measure the length of a task (but not "in a simple clock-like fashion" (p57); Schafer and Schiller 2023). "Some time cells encode space as well. In the brain, in fact, physical and temporal space may be bound together" (Schafer and Schiller 2023 p57).

Grid-like patterns of activation of cells in the entorhinal cortex have been found for abstract associations (eg: two images) (eg: Constantinescu et al 2016). This idea has been applied to the social world - "people maps" (Schafer and Schiller 2023).

"That the same mapping system may underlie navigation through space and time, reasoning, memory, imagination and even social dynamics suggests that our ability to construct models of the world might be what makes us such adaptive learners. The world is full of both physical and abstract relations. Road maps of city streets and mental maps of inter-related concepts help us make sense of the world by extracting, organising and storing related information" (Schafer and Schiller 2023 p59).

3.10. APPENDIX 3B - EPSTUDE ET AL (2022)

Epstude et al (2022) observed that TAP provides "fertile ground for partisan reasoning. Counter-factual events, by definition, did not occur and hence cannot be verified. People may imagine counter-factual events that fit with their beliefs and motivations, asserting it 'almost happened' without the risk of being proved wrong. We propose that, when people reflect counter-factually about political events, political partisanship predicts what they imagine as well as what they infer — in other words, both the content and the conclusions of their counter-factual thinking" (p1).

In their studies Epstude et al (2022) tested the main hypothesis that "partisans flexibly accept and generate either upward or downward counter-factuals that are consistent with the preferred ideological stance or inconsistent with the opposed ideological stance" (p2). In this context, "upward" refers to more negative counter-factuals than actually happened and "downward" more negative.

In the first two studies (Study 1a and 1b), 201 and 192 US adults were recruited online with half of each group self-identifying as Democrat and half as Republican. They were presented with counter-factual statements related to the recent presidency, like: "If Trump had not passed the tax cuts, then the economy would currently be much better [worse]" (two versions of each statement). The response options varied from "extremely plausible" (5) to "extremely implausible" (1). Overall, a counter-factual statement was rated as more plausible when it aligned with the political view than misaligned (figure 3.1).

Study 2, with 190 more participants, used other recent US political events - eg: "If Senate Republicans hadn't blocked Obama's appointee for the Supreme Court...", with the options "then things would have been better" or "then things would have been worse". The choice of a positive or negative counter-factual option was more likely to fit with the political view.

These studies supported the main hypothesis, and showed that both political partisans were prone to cognitive bias in TAP.

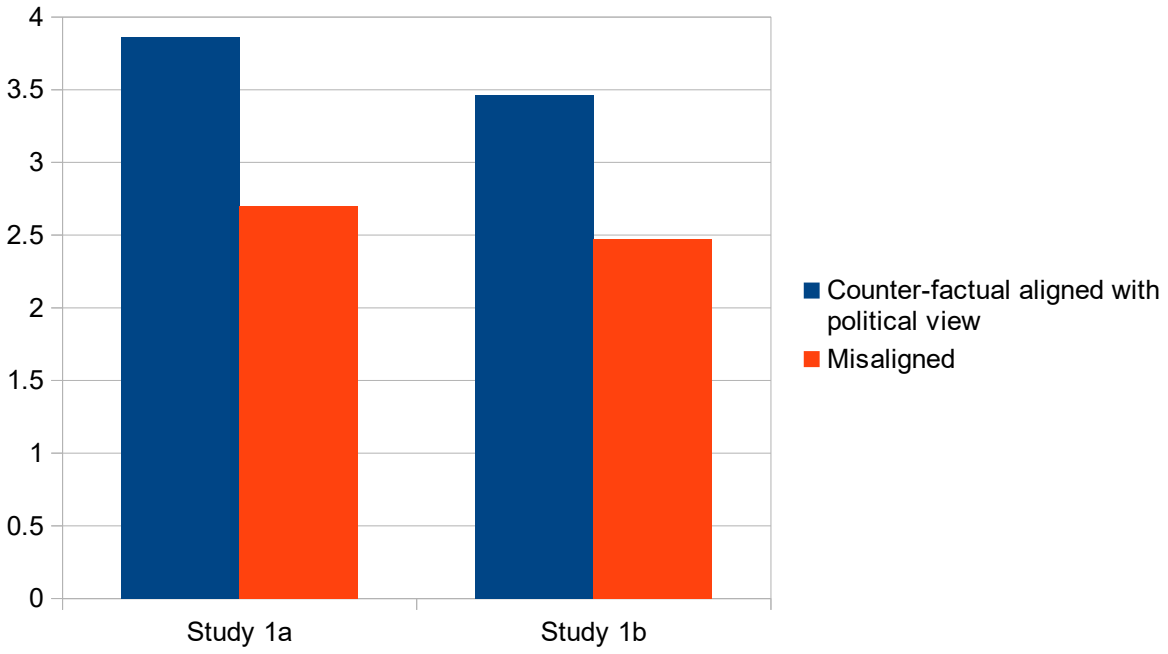

Figure 3.1 - Mean plausibility score (out of 5) in Study 1a and 1b.

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4. ROUTE NAVIGATION

Learning and recall are enhanced with salient stimuli. For example, on route-learning tasks, a brightly-coloured landmark aids correct recall of the direction at a junction (Davis et al 2017).

Caduff and Timpf (2008) proposed three factors in the salience of a landmark - visual (eg: colour; size), structural (eg: proximity to a decision point), and semantic salience (ie: "salience due to personal, cultural, or historical meaning"; Redhead et al 2023 p618).

Redhead et al (2023) focused on nostalgia as an example of semantic salient stimuli in their two experiments. Specifically, fond and personally meaningful memories of childhood and/or close relationships.

Experiment 1 - Sixty participants in their 20s learned a route through a virtual maze. The landmarks at decision points in the maze showed pictures of popular music artists and TV characters, either popular during the participants' youth (nostalgia condition) or recent pictures (control condition). For example, a picture of the "Dr Who" actor 10 years ago (Matt Smith) or the recent actor (Jodie Whittaker). The time to complete the virtual maze was significantly faster in the nostalgia than control condition.

Experiment 2 - This experiment used the same basic design with two differences - the landmarks were at decision or non-decision points along the route, and the landmarks were presented during learning but removed in the test trial. The participants were 48 high-school students.

Nostalgia landmarks improved learning when placed at decision and non-decision points, and when used in learning and subsequently removed in the test, compared to control landmarks.

So, in summary, "compared to more recent but equally recognisable landmarks, nostalgic landmarks enhanced spatial performance on a route learning task" (Redhead et al 2023 p626).

The researchers commented on the application of their findings: "Navigating unfamiliar spaces can be challenging..., particularly within large-scale, multi-level indoor environments including libraries, museums, shopping centres, and hospitals... More often than not, these environments present long corridors and repetitive

designs, making them confusing and disorientating to navigate. Infusing landmarks with nostalgia could help address these design pitfalls by providing a meaningful visual aid" (Redhead et al 2023 p627). This will be even more so for individuals with neurological conditions like Alzheimer's disease.

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5. MISCELLANEOUS

5.1. MULTI-TALKER SITUATIONS

Loud and quiet voices talking simultaneously are processed differently. The louder voice produced activity in the auditory cortex whether an individual was focused upon it or not, while the quieter voice required attention to be processed (Murugesu 2023). Raghavan et al (2023) measured the brain activity of seven individuals conscious while undergoing surgery for epilepsy. They listened to stories read by a male and a female speaker, initially individually (control condition), then two talkers at once with one designated as the target and the other as the non-target.

It is easier when the target talker is louder than the background voices (known as "glimpsed target") than when the target talker is quieter (known as "masked target" or "glimpsed non-target") (Raghavan et al 2023).

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5.2. PSYCHOLOGICAL CLEANSING

Cleansing behaviour includes personal hygiene, like washing hands, and brushing hair, and household tasks (eg: washing the dishes; vacuuming the floor). "Although norms regarding the form and frequency of cleansing vary between societies and historical periods..., the existence of hygienic care is a human universal" (Lee and Schwarz 2021 p1).

Lee and Schwarz (2021) explored the psychology cleansing, beyond the obvious hygiene benefits of handwashing, for instance. For example, Xu et al (2012) found that, in a gambling game, participants who lost

continually reduced their subsequent bets (and the opposite for winning continually). But, if in the middle of the game, participants washed their hands (under the pretence of testing a new soap product), their bets returned to the original level. It was as if the losing or winning streak was washed away. This is the first type of "cleansing effects" (according to Lee and Schwarz 2021) - ie: "effects of cleansing-related manipulations on psychological outcomes" (p2).

The second type is "effects of psychological manipulations on cleansing-related outcomes" (Lee and Schwarz 2021 p2). Individuals ostracised in a co-operative computer game, for instance, were more likely to purchase cleansing (but non-cleansing) products (Poon 2019).

To explain these behaviours, Lee and Schwarz (2021) proposed a "grounded theory", where "mental processes (eg: knowledge, language, thought) do not reside in a layer of amodal symbols abstracted and detached from sensori-motor capacities for perception and action. Instead, the mental is grounded in the physical... Activating one activates the other" (p5).

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6. SWEARING

Swearing is "the use of specific, negatively charged and often emotionally loaded terms, which are taboo in a given language/culture and thus have strong potential to cause offence... It can be described as the use of words that 'have the potential to be offensive, inappropriate, objectionable, or unacceptable in any given social context' (Beers Fagersten 2012...)" (Stapleton et al 2022 pp1-2).

Singleton (2009) described three elements of swear words – they relate to taboo subjects, have literal and non-literal meanings, and their use can be cathartic. The main taboo subject areas include religion (eg: "damn"), sex and sexual body parts (eg: "cunt"), and bodily excretions (eg: "shit") (Stapleton et al 2022).

"With reference to these categories, Hughes (1998...) notes that 'swearing shows a curious convergence of the high and the low, the sacred and the profane'. Of course, even within these categories, there is some conflation, for example, between sexual versus excretory functions and body parts. There is also variation in the offensiveness of some of these core words/categories over time. Thus, the religious category, while still containing recognisable swear words, is likely to be less offensive to many people in contemporary society than it might have been in the past, and/or to constitute, today, a 'milder' form of swearing than many of the words in the sexual/excretory categories. By contrast, the ''lower'' physical faculties of copulation, defecation and urination' (Hughes 1998...) have become much more prominent as swear word referents" (Stapleton et al 2022 p2).

Stapleton et al (2022) outlined the issues related to the power of swearing:

1. Emotional experience including catharsis and arousal - "Emotion is consistently cited in motivations for and perceptions of swearing, on both a cathartic and an expressive level; swearing is perceived by speakers to carry more emotional force than other forms of language; and empirical research confirms a strong link between swearing and emotional arousal" (Stapleton et al 2022 pp3-4).

Swearing in the first language is perceived as more emotionally intense than in languages acquired later in life by multi-lingual speakers (Stapleton et al 2022).

2. Attention and memory – Swear words gain more attention and produce stronger memory recall than non-taboo words in experiments.

For example, Jay et al (2008) (Experiment 1) presented students with 36 words individually taken from three categories – taboo (eg: "cock"), neutral (eg: "brother"), and emotional non-taboo (eg: "cuddle"), and asked them questions like "Is the word in capital letters?". Later there was a memory tests for the words, and average recall was 39% for taboo words compared to emotional (13%) and neutral (7%) words.

3. Physiology – Swear words produce increased autonomic nervous system activity compared to neutral or non-taboo words in experiments (eg: Jay et al 2008: Experiment 2).

4. Pain tolerance and relief – Stephens et al (2009), for example, found that participants could hold their arm in ice water for longer when allowed to swear than use non-swear words (mean 190 vs 146 seconds).

5. Interpersonal functions – The distinction has been made between "annoyance swearing" and "social swearing" (Ross 1960). Concentrating on the latter type, swearing can be used directly as an insult or to intensify an insult, or to offend (ie: negative functions). While swearing can be used to enhance relationships in a group (ie: positive functions).

For example, Beer Fagersten (2017) found benefits for YouTuber's in building para-social relationships with followers, while hypothetical Italian local political candidates who used swear words in fictitious blogs (eg: "is up shit creek") received more positive evaluations than non-swearers (eg: "is in a tragic situation") (but not necessarily likelihood to receive vote rating). Gender was also important, and female swearers did poorer. (Cavazza and Guidetti 2014).

In summary: "Swearing produces effects that are not observed with other forms of language use. Thus, swearing is powerful. It generates a range of distinctive outcomes: physiological, cognitive, emotional, pain-relieving, interactional and rhetorical" (Stapleton et al 2022 p1).

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7. CONCEPTS AND SOCIAL INTERACTION

7.1. INTRODUCTION

"Concepts represent the building blocks of knowledge; they are crucial for thinking, inferring and interacting with the environment. They are the 'glue' that connects our past, present and future experience. Concepts are typically investigated in two ways: in their relation to categorisation — they can be considered as the cognitive and mental aspects of categories — and as instruments of thought" (Borghi et al 2022 p1). The key questions are what are concepts, their formation, and their relationship to language (Borghi et al 2022) [11].

But concepts do not exist in a vacuum, they arise from social interactions, or in "situated interactions", to be more specific (Borghi et al 2022). "Studies show that interaction facilitates abstract thought and problem-solving and reveal that emotions and social interaction are paramount for abstract concept acquisition and use" (Borghi et al 2022 p2).

There is another issue, Borghi et al (2022) explained, of "how different ways of interacting with ourselves potentiate our concepts and cognition. Language is a powerful instrument that enriches our cognitive abilities. Work on inner speech has recently had a novel impulse, showing that we use different kinds of inner speech — monologic and dialogic, condensed and expanded — and that inner speech influences and enhances our thinking processes" (p2).

[11] The traditional view of concepts is that they "derive their semantic content by being grounded in perception, action and introspection, with 'grounding' being defined as the process through which representations are connected to what they are about, the capacity to autonomously link them with referents in the outside world" (Mannella and Tummolini 2022 p2). An alternative to this "grounded cognition" view is that concepts emerge from an intrinsic motivation of competence acquisition (Mannella and Tummolini 2022).

Introducing a special issue of "Philosophical Transactions of the Royal Society B", Borghi et al (2022) outlined the following key areas of interest for concepts and social interactions:

i) Defining concepts.

ii) Concepts emerging from social interactions:

a) During development.
b) During dialogue.
c) In the brain.

iii) Concepts and interaction with ourselves:

a) In sensori-motor and inner experiences.
b) Inner speech.

7.2. DEFINING CONCEPTS

Shea (2022) saw concepts as "the recombinable components of conscious, deliberate thought" (p1). They are "found in our judgements, hypotheses, intentions, aims and occurrent desires and beliefs. Their subject matter encompasses the concrete and abstract, particulars and properties, the physical, logical and socio-cultural, and runs from the mundane to the extraordinary: DOG, NUMBER, HEAVY, AND, MONDAY, BUS, MANDELA.1 They are sub-propositional: a concept does not make a claim about the world on its own, but only when combined with other concepts into a complete thought" (Shea 2022 p1).

Traditionally research has focused on the categorisation of concepts, but Shea (2022) argued that "just as important is the capacity to use concepts to think through what to do, or to work out what is the case, unprompted by a current incoming stimulus. These episodes of thinking begin with a conceptual thought" (p1). Each concept provides access to information, whether it be stored memories or running "simulations" of what could be. Simulation is particularly important in reasoning (eg: "if I do X, then Y will follow, but if I do X1, then Y will not follow"). A concept is a "plug and play device", argued Shea (2022), that allows the "special-purpose systems" of cognition to run the relevant simulation (eg: planning a route; making a particular comment to a person).

Shea (2022) offered the example of the thought of "soldiers mounted on polar bears"; "you will start to

imagine what that will look like and what might happen. There is considerable evidence that thinking with concepts activates representations in multiple special-purpose systems — sensory, motoric, affective, evaluative and amodal. The power of conceptual recombination lies not simply in the capacity to recombine labels or words in a language of thought. Its power lies in the capacity to simulate scenarios corresponding to our thoughts" (p4).

Concentrating on linguistic concepts, Enfield (2022) distinguished between the "O-axis" and "I-axis". The O-axis (O = objective) focuses on the sign standing for an object, "where the sign is something we can directly perceive, such as the sound of a word, and the object is a concept, or the sense of a word, often implying reference to a corresponding class of physical entities (a category) in the world" (Enfield 2022 p1). The I-axis (I = interpretation) describes the link between concepts and social interactions. "On the O-axis we can ask 'What is the definition of scalpel?', while on the I-axis we can ask how people respond to the word. What does the word give rise to in the flow of social interaction? So, we might hear a surgeon utter the word scalpel and see their assistant pass a scalpel in response" (Enfield 2022 p1).

Enfield (2022) emphasised the need for both axes to fully understand linguistic concepts: "Without social functions, the signs that denote linguistic concepts would not circulate, and the conventionalised concepts they denote would not be reproduced and would not exist. Linguistic concepts are not thoughts that happen to be made public. Linguistic concepts are social events that happen to become thoughts" (p6).

7.2.1. Abstract Concepts

Langland-Hassan and Davis (2022) were interested in abstract concepts, which they considered based around two central questions:

i) What makes a concept abstract, and what makes one concept more abstract than another one?

ii) What is the relationship between abstract concepts and language?

Concerning the first question, "Borghi et al [2017]

describe abstract concepts (such as FANTASY, FREEDOM and JUSTICE) as 'lacking bounded and clearly perceivable referents' and as being 'more detached from sensorial experience than concrete ones'... Borghi et al [2018] also note that abstract concepts 'do not possess a single and perceptually bounded object as referent', and have a content that is 'more variable both within and across individuals'" (Langland-Hassan and Davis 2022 p2). Barsalou (2003) emphasised that abstract concepts are "detached from physical entities", and are "more associated with mental events" (quoted in Langland-Hassan and Davis 2022).

Researchers have tended to study abstract concepts using "concreteness ratings". Brysbaert et al (2014) explained: "Some words refer to things or actions in reality, which you can experience directly through one of the five senses. We call these words concrete words. Other words refer to meanings that cannot be experienced directly but which we know because the meanings can be defined by other words. These are abstract words. Still other words fall in-between the two extremes, because we can experience them to some extent and in addition we rely on language to understand them. We want you to indicate how concrete the meaning of each word is for you by using a 5-point rating scale going from abstract to concrete" (quoted in Langland-Hassan and Davis 2022).

A similar notion of concepts is "abstractness-as-imperceptibility". Put simply, whether the concept can be perceived by the senses. That seems very much like concreteness as defined above, but Langland-Hassan and Davis (2022) saw concreteness and imperceptibility as interacting to produce four classes of abstract concepts:

a) "Minimally abstracted concepts of perceptibles" - These concepts can be perceived by the senses, and show perceptual similarities to other concepts (eg: cow, table, cup).

b) "Highly abstracted concepts of perceptibles" - Similar to (a), but the concepts have relatively few similarities to other concepts (eg: object, organism, plant).

c) "Minimally abstracted concepts of imperceptibles" - Imperceptible to the senses, but share similarities (eg: seven, electron).

d) Highly abstracted concepts of imperceptibles" - Imperceptible with few similarities (eg: value, mental

state).

Langland-Hassan and Davis (2022) wondered whether categorisation of these different types of concepts varies. The categorisation of concepts has been studied with the "Cactus to Camel test", where a participant is presented with a target image and must link it to one of four other images. For example, a target image of a passenger train, and the images of a motorcycle, a tractor, a small truck, and a bus. The choice of bus suggests a single category of "mass-transit vehicles" (Langland-Hassan and Davis 2022).

Another example might be a target object of electric socket plug, and a choice of a candle, flashlight, lantern and lightbulb. Matching the plug with the lightbulb suggests the concept "electricity" (Langland-Hassan and Davis 2022).

Langland-Hassan et al (2021) used this test, and after the choice of matching image, participants were asked to give one word that linked the two images. The linking word was then rated for its "concept concreteness". The linking word and its concreteness could vary depending on the context (ie: the choices), and Langland-Hassan and Davis (2022) called this "trial concreteness". The linking word varies in concreteness depending on the visual similarity of the choices, for instance, even if the same word is used.

For example, both linking words in table 7.1 are "dog", but the trial concreteness is different because of the visual similarity differences in the two trials. In trial (a), the non-matching choices are very different to those in trial (b).

Target Image	Choice Images	Answer	Linking Word
German shepherd	Fork, Knife, Spoon, Poodle	Poodle	Dog
German shepherd	Hyena, Tiger, Lion, Chihuahua	Chihuahua	Dog

(Source: Langland-Hassan and Davis 2022 figure 1)

Table 7.1 - Two examples of the Cactus to Camel test.

Langland-Hassan and Davis (2022) asserted that "we see minimal value in assigning a fixed degree of abstractness to any individual concept, given that this value will itself be a kind of averaging across very many

contexts where varying degrees of abstraction were required for the behaviours we associate with use of the concept. It remains true that some concepts will, on average, require more abstraction for their use than others. In that sense, which averages across all usages, we can say that one concept is more abstract (in tending to require, for its use, more abstraction away from differences) than another. Concepts of more inclusive categories (such as MAMMAL) will tend to require more abstraction than narrower categories (such as DOG). Nevertheless, depending on the context, these differences may be reversed on any particular task that aims to test facility with a concept. If we wish to investigate the support language may provide for abstract conceptual abilities, it is more useful to rate the degree of abstraction required by a particular use of a concept in context" (pp9-10).

A distinction is usually made between concepts concerning objects (entity categories) and concepts concerning relations (relational categories) [12]. The former are directly perceived and the latter subsequently inferred in one view, while an alternative perspective is that "relations are perceived directly, as they are part of the anticipatory organisation of the cognitive system that were stabilised while acting in a given environment" (Raczaszek-Leonardi and Zubek 2022 p3). This perspective can be called "action-first" or "interaction-based" (Raczaszek-Leonardi and Zubek 2022).

"Affordances" is an important idea here. What is directly perceived are "relational properties of an organism in its environment, which can guide possible actions. Instead of perceiving the objective shape and size of a chair, an agent notices that the shape and size are just right to offer the possibility of sitting" (Raczaszek-Leonardi and Zubek 2022 p3).

Finding similarities and differences between concepts from the same semantic categories "is easy – at least for adults" (Liu and Lupyan 2022 p1). For example, a doctor and a nurse are judged as more similar than a doctor and a carpenter.

"However, people's ability to appreciate semantic

[12] Twardowski (1924 quoted in Raczaszek-Leonardi and Zubek 2022) called relational concepts examples of "analytical concepts", and entity concepts "synthetic concepts". The distinction is based around the "imaginability" of a concept. "Analytical concepts are constructed out of percepts or other concepts by selecting some parts of the perceived whole that cannot be imagined on their own, ie:. without entities that have these properties or exist within certain relations (for example, having a colour, being long, or being a daughter). By contrast, entity categories are Twardowski's synthetic concepts, as they are characterised by 'wholeness'" (Raczaszek-Leonardi and Zubek 2022 p7).

similarity is not limited to comparing items from the same semantic domain. When asked to align concepts from different semantic domains, people sometimes show uncanny convergence. For example, when asked 'If science were a colour, what colour would it be', 40% respond with 'green'. When asked in the same manner, to map philosophy to a beverage, 20% map it to tea. When mapping professions to musical instruments, 32% map doctors to pianos while 26% map nurses to violins [Liu and Lupyan 2020 quoted in Liu and Lupyan 2022] (these two responses are the modal responses and greatly exceed the probability of these instruments being mentioned by chance alone)" (Liu and Lupyan 2022 p1).

Liu and Lupyan (2022) performed further experiments on cross-domain mappings of concepts. Participants were asked, "If a nurse were an animal, they would be a(n)", and 20% answered "cat". Liu and Lupyan (2022) ended: "Our results show that people tend to converge in how they map between concrete domains and that they do so either by making use of abstract information encoded as part of the concrete concepts that are being mapped, or by actively projecting these concepts into a more abstract semantic space so that they can be aligned" (p13).

Such studies suggest that concrete and abstract concepts are stored based on dimensions like valence. "It is reasonable to talk about positively and negatively valenced animals, jobs, beverages, colours etc. and one can imagine that mapping between these domains is informed by how similarly valenced the items are. For example, if part of our representation of 'rat' is its negative valence, then when we are asked 'If a rat were a job, what job would it be', we tend to think of negatively valenced jobs" (Liu and Lupyan 2022 p2).

7.3. CONCEPTS EMERGING DURING SOCIAL INTERACTIONS

7.3.1. During Development

The study of the brain during learning has tended to be a "single-brain" approach (Gazzaniga et al 2002) (ie: a focus on how the individual learns), but more recently a "second-person neuroscience" approach (Redcay and Shillbach 2019) has emerged. This approach "studies cognitive processes in interaction, including the back-and-forth dynamics between two or more people" (De Felice et al 2022 p1).

De Felice et al (2022) argued for this approach suggesting that "(solitary) action per se may not be

enough, but rather that action in interaction may be key to support human learning, as exercised via many forms including gestures, object manipulation and language" (p2). This interactive learning (ie: learning with others) is distinct from learning from others as in observational learning and imitation (De Felice et al 2022).

The few studies of interactive learning mostly concern language acquisition. For example, Kuhl et al (2003) taught nine month-old "English-speaking" babies to distinguish Chinese Mandarin sounds in one of three conditions - in interaction with a native speaker, via video, or audio recording. "Despite equivalent exposure time and content of Chinese sounds, only the group who engaged in live-interaction with the teacher showed learning, and being exposed to videos or sound recordings was associated with no learning. While this study is not strictly looking at knowledge-based learning (eg: concepts), it provides strong evidence for the crucial role of interaction in children's learning over non-interactive learning methods" (De Felice et al 2022 p3).

Similar research has shown the benefits of interactive learning for adults. Jeong et al (2021), for example, taught Japanese-speaking adults Korean spoken words via videos depicting social interactions, or in the translation of the words. Learning was better in the first condition.

As mentioned above, there is little research on interactive learning of concepts. De Felice et al (2022) speculated: "Interactive teaching would allow a learner to try out a new concept and explore how it relates to other concepts with immediate feedback, which is likely to provide richer and more robust learning" (p8).

In terms of what is happening in interactive learning, De Felice et al (2022) admitted that it is difficult "to disentangle the contribution of specific factors associated with social contexts that benefit human learning. It is hard to separate individual components because live interaction cannot be easily deconstructed. Future studies using virtual reality might be able to do so by experimentally manipulating which aspects of interaction are most important to learning" (p8).

In another study of interaction in learning, Karmazyn-Raz and Smith (2022) observed thirty-two toddler-parent interactions for ten minutes in a playroom with a choice of 32 toys. The choice of toys was not

random, but showed a pattern that provided a scaffolding for learning. “Episodes of toy play may be experienced and remembered, as are stories, as a coherent system of meaningful relations” (Karmazyn-Raz and Smith 2022 p11).

Viertel et al (2022) studied the acquisition of abstract concepts specifically in the form of religious words like mercy, blessing, and holy. “Between the ages of 8 and 9 years old, children achieve the largest learning progress in acquiring the meaning of abstract words [...] In contrast with concrete words, the challenge in learning abstract words is to systematically connect the elements that constitute a concept, which are dislocated across space and time” (Viertel et al 2022 p2).

Three processes are involved in the acquisition of abstract concepts (Viertel et al 2022):

i) Emotionalisation - The association of an emotional experience with the word as way to anchor the novel meaning.

ii) Perspectivation - “For example, when reading a story aloud, the caregiver could take on the perspective of a character and convey an emotion from that character’s perspective, ie: she or he focuses on a specific mental or emotional state” (Viertel et al 2022 p2).

iii) Interactionist contextualisation - A concept is co-constructed in social interactions.

Viertel et al (2022) explored these processes in a pilot study with eight 7-8 year-olds and caregivers in Germany and the word “mercy”. Firstly, the caregiver read the Bible story of Jonah to the child and the concept of mercy was discussed. Then the child was presented with pictures, some linked to the story, and asked to choose those showing mercy.

There was evidence of emotionalisation and perspectivation being used. For example, the latter was seen in the caregiver encouraging the child to perceive another person’s feelings or imagine their motives in the reading session. The children, however, were not able to generalise mercy to secular stories, and instead used related concepts like kind.

Viertel et al (2022) explained their thinking: “We chose the word mercy as an object of investigation because it is a prototypical religious word which anchors

emotionalisation and perspectivation through language. Our starting point was that the mere naming of semantically relevant aspects is not sufficient to experience the profound meaning of it. Instead, an enrichment by the related linguistic means is necessary but has to be constructed by child and caregiver together" (p7).

7.3.2. During Dialogue

"Dialogues are everyday co-operative joint activities, involving more than one person who seeks to comprehend each other. Given how common it is and how natural it feels to take part in dialogues (from ordering a coffee in a bar to chatting with friends over a meal), one might risk overlooking the cognitive challenges that dialogue offers to speakers" (Gandolfi et al 2022 p1). Mutual understanding here involves alignment – ie: when the speakers "focus on the same aspects of the world and conceptualise them in the same way" (Gandolfi et al 2022 p1).

But this process is a collaboration, and "interlocutors share control control over the dialogue by continuously monitoring and comparing their own and their interlocutor's contributions, by drawing on metacognition and social cognition, and specifically by meta-representing whether they believe they and their interlocutor are aligned or not. This process allows speakers to build similar representations and align on their way of understanding complex phenomena in the world without having to build elaborate inferential systems of beliefs about their own and their interlocutor's understanding" (Gandolfi et al 2022 pp1-2). Alignment has greater significance for abstract than concrete concepts.

Pickering and Garrod (2021) explained that speakers collaborate in "the shared workspace" (ie: "the set of salient signs and associated context that are at both the speakers' disposal"; Gandolfi et al 2022 p2).

A similar process is the "division of linguistic labour" (DLL), which is the sharing of knowledge about a particular concept. Originally seen as novices dependent on experts for the identification of some concepts (eg: Putnam 1975), Andrade-Lotero et al (2022) broadened the framework "to capture situations in which the members of a community do not necessarily differ in their overall level of knowledge, but rather in their perspective or kind of knowledge" (p1).

Put another way, the goal of communication for individuals is to "make use of cognitive specialisation to increase the efficiency of their own cognitive processes" (Andrade-Lotero et al 2022 p3), which is contrary to the "common ground" view (eg: Clark 1966) that characterises "communication as a process that requires a shared background of knowledge for the activity to be successful" (Andrade-Lotero et al 2022 p3). The "pooled ground" approach (eg: Raczaszek-Leonardi et al 2014) is another way of describing the DLL.

Andrade-Lotero et al (2022) reported an experiment on the DLL. Eighty-four students at a university in Colombia were recruited for the two conditions – solitary and paired. The task was to identify correctly the breed of dog shown (eg: "Is this dog a Cairn terrier?") either working alone or with a partner. More accurate classification occurred in the paired condition, particularly when the players asked their partner for clarification of the breed.

Olsen and Tylen (2022) argued that social interaction aids the forming of abstract representations (abstraction): "interaction can stimulate processes of abstraction when varied individual information is integrated and generalised across members of a group, facilitating the flexible transfer of experiences and knowledge between contexts" (p7).

This idea has been tested in experiments involving solving problems working alone or in pairs. For example, Schwartz (1995) found that pairs produced more abstract representations of science problems which aided their solution than individuals alone. While Voiklis and Corter (2012) found similar results in a complex, rule-based categorisation task.

"Interpersonal attunement" is a more general term that has been used. "People tend to 'fall in synchrony' in social interactions, eg: through spontaneously aligning rhythmic behaviours, such as gait and clapping or adopting others' mannerisms, from shaking a foot or scratching the head to adopting each other's speech styles, emotions and moods [...] All of these instances of interpersonal attunement can be thought of as facilitating human communication, collaboration and eventually trust-based social relationships..." (Bolis et al 2022 pp1-2).

Misattunement can be seen as the basis of psychopathology (eg: "dialectical misattunement hypothesis"; Da Costa et al 2022).

7.3.3. In the Brain

The social qualities of words (or socialness) has an impact on the structure of concepts and the representation of our semantic knowledge in the brain. This is particularly important for abstract words (Pexman et al 2022).

For example, Troche et al (2014) asked participants to rate 200 concrete and 200 abstract English nouns on twelve dimensions, which factor analysis reduced to three underlying factors – affective association/social cognition, perceptual salience, and magnitude. "Abstract word meanings relied more heavily on affective association/social cognition than did concrete meanings" (Pexman et al 2022 pp2-3). As similar idea of clusters was seen in research with Italian nouns (Villani et al 2019), though the clusters were different – philosophical/spiritual concepts; physical, spatio-temporal and quantitative concepts; emotional/inner state concepts; and self and sociality concepts, while Vargas and Just (2020) found patterns in neural signatures as participants thought of 28 abstract words in a functional magnetic resonance imaging scanner (3 latent factors – verbal representation, externality/internality, and social content) (Pexman et al 2022).

Concentrating on the brain and socialness, there are two main theories (Pexman et al 2022):

i) The "social knowledge hypothesis" (eg: Olson et al 2013) – Multiple independent stores in the brain compose the semantic system, and the dorso-lateral aspects of the anterior temporal lobe (ATL) appears to represent social knowledge (according to neuroimaging studies).

ii) The "graded semantic hub" explanation (eg: Binney et al 2012) – This also focuses on the ATL, but "the whole ATL comprises a unified semantic representational space, all of which is engaged by the encoding and retrieval of concepts, and by concepts of any kind" (Pexman et al 2022 p4).

Pexman et al (2022) noted that there is no agreed definition of "socialness" which hampers theories and research. For these researchers, socialness, "broadly construed, is a dimension of word meaning that can be distinguished from other dimensions such as concreteness and valence. Moreover, there is some evidence that socialness is reflected within the organisation of neural

systems that support semantic processing. It remains to be seen whether this is indicative of social words being a distinct type, or whether socialness is just one of many dimensions that define a unified domain-general semantic space" (Pexman et al 2022 pp5-6).

Activity in the insula, the amygdala, and several cortical areas have been found for social concepts (Lopes da Cunha et al 2022). "Social concepts are those that primarily evoke socio-interactive behaviours, traits or circumstances. In the linguistic domain, these can be conveyed by verbs, nouns, adjectives and adverbs with positive or negative valence (such as help, kindness or friendly, and resent, envy or jealous)" (Lopes da Cunha et al 2022 p1). Also the cerebellum and its connectivity to the cortex is involved according to research by Lopes da Cunha et al (2022).

Fifteen Spanish speaking cerebellar ataxia (CA) patients were compared to 29 healthy controls (HCs). CA is "a disorder typified by cerebellar atrophy and abnormal cerebello-cortical connectivity, as well as disruptions of socio-cognitive domains — such as emotion attribution, mental state recognition and theory of mind" (Lopes da Cunha et al 2022 p2). Comprehension of two types of passages read out to the participants was the outcome measure. The text was classed as social (involving interpersonal events – eg: "Immediately, he went over to Juan and earnestly asked for a favour"; p4) and non-social (a single person's actions – eg: "Afterwards, he would read a book and listen to classical music on the balcony"; p4). There was no difference in comprehension scores for the non-social text, but the CA group had significantly lower scores for the social text.

7.4. CONCEPTS AND INTERACTION WITH OURSELVES

7.4.1. In Sensori-Motor and Inner Experiences

One idea is that concrete concepts involve sensori-motor neurons in the brain (eg: the activation of leg-related neurons when thinking about the concept "kick") (eg: Barsalou 2008), but this is not possible for abstract concepts. The solution is "emotional grounding" (or affective grounding" or "affective embodiment") (eg: Lenci et al 2018). Abstract concepts activate emotion-related neurons in the brain (Winter 2022).

The main line of evidence in favour of emotional grounding is the correlation between "emotional

experience" (defined as "the relative ease with which a concept evokes emotional experiences"; Winter 2022 p2) and the abstractness of a concept (eg: Newcombe et al 2012). The studies, however, are mixed in their findings (Winter 2022).

Winter (2022), using words in Cantonese, Mandarin Chinese, Croatian, Dutch, French, German, Indonesian, Italian, Polish, and Spanish, found that "the idea of emotional grounding only characterises a small sub-set of abstract concepts" (p1), and depending on how concreteness/abstractness is operationalised, "concrete concepts are rated as more emotional than abstract ones" (p1).

Banks and Connell (2022) found a more complex picture in their three experiments. They found that "both concrete and abstract categories are strongly grounded in multi-dimensional sensori-motor experience. Both domains were dominated by vision and, to a lesser extent, head movements, but concrete categories were more grounded in touch and hand-arm action, while abstract categories were more grounded in hearing and interoception. Importantly, this pattern of grounding was not uniform, and sub-domains of concrete (eg: ingestibles, animates, natural categories and artefacts) and abstract (eg: internal, social and non-social) categories were grounded in different profiles of sensori-motor experience" (Banks and Connell 2022 p1).

English-speaking participants were asked to rate concepts as to the extent each was experienced via six perceptual modalities (vision, hearing, taste, smell, touch, and interoception) and five body area actions (hand-arm, foot-leg, head, mouth, and torso). The eleven dimensions were combined to give each concept an overall score, where a higher score was a stronger sensori-motor grounding.

The mean score for concrete concepts was slightly higher than for abstract concepts, but "both abstract and concrete categories had member concepts that were quite weakly (eg: nano-second as a unit of time, hydrogen as a chemical element) and strongly (eg: pain as a symptom of illness, shower as a bathroom fixture) grounded" (Banks and Connell 2022 p3).

The mental mapping of emotional concepts is an area of interest. Two dimensions appear important – hedonic valence (eg: pleasure-displeasure), and level of physiological activation/arousal (Barca et al 2022). Barca et al (2022) argued, however, that "emotional

concepts are not processed in the void, but rather in the context of other emotional stimuli and more broadly of a variety of factors (eg: emotional dispositions, physiological or interoceptive states) that are known to impact emotion perception and representation" (p2).

They supported this view with experimental evidence. Thirty adults were presented with 24 emotional words in sets of three, and had to choose two that were similar. The context (ie: the other words presented) influenced the choices, but more so for words perceived as low on the arousal dimension.

The naming of smells involves olfactory concepts, which may be abstract (eg: citrusy smell") or concrete (eg: "the smell of lemon") (Deroy 2022). Deroy (2022) saw an over-representation of abstraction in relation to olfaction, which is contrary to other senses. She proposed two reasons, as Borghi et al (2022) explained: "The first is that abstract concepts make people feel less authoritative and defer more to others; hence there would be a benefit in terms of social cohesion. The second is that converging on abstract terms would be easier. Hence, among the adaptive advantages that the use of abstract terms can provide, she identifies the social feedback received by others, which could increase people's confidence that their communicative intention has been understood. Both hypotheses strongly highlight the link between concepts, metacognition, and social interaction" (p5).

Olfactory terms can be plotted on two dimensions – degree of abstractness, and specific-general. For example, "the smell of lemon" is low generalisation and abstractness, while "acrid smell" is high on both dimensions (Deroy 2022).

Naming smells is difficult, and Jonsson and Olsson (2012), for example, found around 20% accuracy for common smells. Naming colours is much better (Deroy 2022). However, there are cultural differences. For example, the Jahai people (indigenous hunter-gatherers who live in rainforests in Malaysia and Thailand) have only 12-15 general smell terms. "Under experimental conditions, the Jahai are as good at naming smells using these general words as they are at naming colours. They are clearly better at odour naming than matched English speakers [Majid and Burenhult 2014], as measured in response times" (Deroy 2022 p3).

Naming common smells involves three stages, according to Oloffson and Gottfried (2015): object perception (ie: identifying a smell), lexical-semantic

integration (ie: finding the name in the memory), and verbalisation (of the answer). There are potential problems at each stage. "When participants struggle to come up with a name for odourants during experiments, some of their difficulties start with not being able to perceptually identify a distinct smell, and/or to construct it as a distinct object for naming. Other limitations, besides difficulties in perceptual identification of single-molecule odourants, make olfaction arduous in the real world. Discriminating and identifying component smells in mixtures remains particularly challenging" (Deroy 2022 p4).

While verbalisation problems include the wording used by the researchers – for example, "What does it smell like?". Deroy (2022) argued that such wording favours concrete responses. Poulton (2020), for example, used the wording, "How does it smell?", and found differences to other studies (Deroy 2022).

7.4.2. Inner Speech (and Language and Thought)

The relationship between language and thought has interested researchers for much of the history of psychology. Simply, there are two views – that language determines thought, or language-independent concept formation occurs. The former is best seen in the (Sapir-Whorf) "linguistic relativity hypothesis" (eg: Whorf 1956). For example, the words in a language for different colours influence the perception of different colours. More recently, the "label feedback hypothesis" proposed that labels "play an active role in perception and categorisation by selectively activating perceptual features that are diagnostic of the category being labelled" (Lupyan 2012 quoted in Henningsen-Schomers et al 2022).

Using computational modelling, Henningsen-Schomers et al (2022) found partial support for the linguistic relativity hypothesis, namely that "'Whorfian' effects should be modulated by the concreteness/abstractness of the semantic categories being acquired, with language labels supporting the learning of abstract concepts more than that of concrete ones" (p1).

Dove (2022) took this position: "Viewing language as a component of multi-modal embodied cognition suggests that the presence, or indeed the absence, of words should influence our reasoning. Words should enhance and transform our cognition in specific ways" (p4). He

proposed the following ways.

Firstly, "words facilitate generalisation. They may serve as representational anchors that help stabilise and organise embodied simulations of experience. Words (but not tones, sounds or emotion responses) have been found to help young children with object individuation. Verbal cues such as the word dog appear to activate more general category representations than non-verbal cues such as the sound of a dog barking" (Dove 2022 p4). Secondly, words focus attention to specific conceptual features, and thirdly, "words may engage background frames or schemas. For instance, the meanings of the English words buy, cost, pay and sell are all understood relative to a commercial event frame. A word like vegetarian makes sense in a society where many people eat meat" (Dove 2022 p4).

The relationship between inner speech ("covert self-directed talk"; Borghi and Fernyhough 2022) and the acquisition and use of concepts is well studied, Borghi and Fernyhough (2022) saw it as more important for abstract concepts. The importance of inner speech in children's development was particularly by Lev Vygotsky (eg: Vygotsky 1987), who viewed "inner speech as resulting from the internalisation of linguistically mediated interactions that are used to regulate cognition and behaviour" (Borghi and Fernyhough 2022 p3).

Borghi and Fernyhough (2022) distinguished between different types of inner speech, including "inner monitoring" (eg: "Do I know this word?") and "inner social metacognition" (or inner dialogue) (eg: "Yes! We used it while talking about...").

Dove (2022) offered two ways in which inner speech helps with uncertainty: "First, it can help us monitor our own concepts by enabling us to trace a word's meaning through its connections to other words. Rehearsing words in working memory can help us evaluate our understanding in an online fashion. Second, inner speech can engage discourse-related knowledge by simulating potential conversations concerning the concept. In other words, it can be used as part of an inner dialogue about the contents of our thoughts" (P6).

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8. SUPERNATURAL ATTRIBUTIONS

Exline and Wilt (2023) considered the concept of "supernatural attributions (SAs): explanations that invoke causes beyond the natural (or material, physical) world (p462). Supernatural beliefs and attributions are held by the majority of people, according to surveys (eg: 79% of Americans in 2022 believed in God) (Exline and Wilt 2023).

Supernatural beliefs include "personal agents — such as gods, the devil, demons, and spirits of deceased people — but they also include impersonal forces such as karma, fate, destiny, and luck. Other supernatural beliefs involve supernatural realms or domains. These might be associated with an afterlife, a domain that exists beyond human conceptions of time, or some form of ultimate reality or consciousness that extends beyond the material plane" (Exline and Wilt 2023 p414). "Paranormal" is an overlapping concept (Exline and Wilt 2023) [13].

Supernatural events are those that "suggest violations of natural laws or glimpses behind the veil, allowing people to see or experience some world beyond this one" (Exline and Wilt 2023 p464). These include miracles, near-death-experiences, and darker experiences related to demons. "But SAs do not require these types of dramatic experiences. Many people will endorse both natural and supernatural explanations for events... They may directly endorse beliefs that supernatural entities can work indirectly through natural events, which could open the door to see supernatural influence on many areas of life, such as health, relationships, and finances" (Exline and Wilt 2023 p465). The ordinariness of spiritual experiences is captured by the "Daily Spiritual Experience Scale" (Underwood 2011), for example.

SAs can co-exist with natural or scientific attributions, and they are part of the culture and everyday lives of some people (Exline and Wilt 2023).

The psychological aspects of SAs can be listed as (Exline and Wilt 2023):

i) Coping resources in times of stress.

ii) Causing distress - eg: temptation by evil spirits; bad experiences as divine punishment.

[13] "Paranormal" "typically refers to phenomena, such as psychokinesis, hauntings, and clairvoyance, which contradict the basic limiting principles of current scientific understanding" (Dean et al 2022 p2). Pechey and Halligan (2011) found that nearly four-fifths of their sample help at least one paranormal belief to some degree of strength.

iii) Guiding personal decisions - "In a national sample of African American adults (Debnam et al 2012), seeing oneself as having an active, collaborative partnership with God correlated with better health behaviours, whereas passive reliance on God correlated with poorer health behaviours" (Exline and Wilt 2023 pp467-468).

iv) Related to moral judgments - eg: adults identifying as transgender or gender non-conforming experience more negative feelings if they believed that God disproved of their gender identity (Exline et al 2021).

v) Fuel conflict - eg: demonic attributions of opponents in recent US elections increased hostility towards them.

Not everybody makes SAs, so what are the factors that predict who will and who won't make such attributions? Exline and Wilt (2023) offered these categories of predictors:

a) Proximal factors - attention (ie: supernatural ideas are accessible), reason (eg: SAs seem "logical" to the individual), and motivation (eg: SAs are more pleasant than other explanations).

b) Contextual and situational factors - Dramatic or anomalous experiences require "big" explanations. "Unusual, exciting events draw people's attention and raise the 'why?' questions that can start an attributional search process. Some people, based on the evidence they consider, will be unable to find a natural explanation. They might continue to search for reasons, categorise the event as mysterious, or make an SA" (Exline and Wilt 2023 p470).

Other situational factors include highly positive events, moral-related situations, being supernaturally tuned (eg: "spooky environment"), and life changing moments.

c) Stable background factors - Four groups of factors can be distinguished here:

i. Holding supernatural beliefs - "If people do not hold any supernatural beliefs, or if they do not believe in the specific entity in question, their non-belief should effectively close the door on SAs unless an event

is so compelling that it leads to a major shift in beliefs. But for other people, thoughts of the supernatural might come to mind very readily, making SAs easy. A major predictor here, not surprisingly, is strong prior belief in the entity in question" (Exline and Wilt 2023 p472).

ii. Psychopathology - "Many psychological disorders could make SAs more likely or affect their content. In the context of psychosis, magical thinking could cause a person to see illusory connections between events or agency behind random events; the quest for an explanation might lead some toward thoughts of powerful supernatural agents (eg: gods, the devil, fate). People experiencing grandiose delusions may have strong motivations to see themselves carrying out special missions from God — or as being specifically singled out for divine or karmic rewards. Paranoid or obsessive-compulsive tendencies might fuel concerns about divine punishment or demonic attack along with self-protective behaviours and actions designed to avoid these dangers. These are just a few possibilities" (Exline and Wilt 2023 p472).

iii. Individual differences - eg: high need for closure; high absorption (ie: being deeply involved in a fantasy); teleological thinking (ie: the tendency to see events as meaningful or purposeful). Not necessarily low analytic thinking or high intuition as the evidence is divided here (appendix 8A).

iv. Socialisation to believe in supernatural beings (ie: cultural differences).

In conclusion, Exline and Wilt (2023) emphasised "SAs as a normal psychological process" (p475), that are widespread, take many forms, and are psychological important for individuals.

APPENDIX 8A - PARANORMAL BELIEFS AND COGNITIVE FUNCTION

There is a relationship between paranormal beliefs and cognitive functions (eg: memory; cognitive biases; analytical thinking). This idea is based in part on a review of forty-three studies (Irwin 1993). Dean et al (2022) updated this review, with particular reference to methodological quality.

In May 2021 four electronic databases were searched using terms like "'paranormal belief' AND thinking".

Seventy-one relevant studies were found, and divided into six categories - perceptual and cognitive biases; reasoning; intelligence, critical thinking and academic ability; thinking style; executive function and memory; and other cognition.

Around two-thirds of studies confirmed the "cognitive deficit hypothesis" (ie: paranormal beliefs are associated with poorer cognitive performance). Specifically, paranormal belief was associated with an intuitive thinking style, confirmation bias (ie: only seeking evidence that supports own view), and poorer reasoning, though there was inconsistency in the findings.

In terms of methodological issues, 60% of all studies had undergraduate samples, and half of these exclusively psychology undergraduates, which "raises doubt about external validity" (Dean et al 2022 p1).

Another concern was that "studies often employ large numbers of measures, metrics and analyses [14], with no clearly identified primary outcome or adjustment of probability levels. These factors necessarily constrain any firm conclusions because of the high probability of Type 1 errors" (Dean et al 2022 p17) [15].

Dean et al (2022) highlighted a further concern that "information about non-respondents was either unreported or reported with insufficient detail to permit an assessment of potential non-response bias" (p17).

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[14] Twenty-six different tests of paranormal belief, including thirteen bespoke measures (Dean et al 2022).

[15] A Type 1 error is mistakenly rejecting the null hypothesis when it is true.

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