Cognition Capabilities and the Capability-affordance Model

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Abstract: Much research has been done on physical and cognitive affordances in designed objects, but little has been done on human cognitive capabilities. This paper applies the capability-affordance model to cognitive agent capabilities and affordances. It develops a cognition-affordance model by identifying cognition resources using the SRK model and cognitive task analysis. It proposes four cognition mechanisms and suggests cognitive capability depends on cognitive mechanisms interacting with knowledge. Affordance possibilities depend on different knowledge paths where existing or new agent knowledge is applied/grown by copying or mutation. Mutation may use existing logic creating new knowledge directly applicable to the real world, or, new theoretical knowledge affordances of imagination. We propose a two axis model to link cognitive affordance and imagination. We propose how perceived and cognitive affordances relate to the perception-action axis and that epistemic-axiological axis relates to the theoretical models of thought to account for creativity in human-agent cognition.

1 INTRODUCTION

Our work focuses on the capability of the object in the environment in terms of people and natural and human designed objects/systems ie 'what could the object do?' and 'how do we measure what it could do? The term 'cognitive affordance' defined by Norman et al., (1988) is widely used to explain combinations of object uses in relation to what is perceived in the environment. Cognitive affordance theory is often used to design human computer interfaces (Hartson, 2003) and in ecological design of systems. However, firstly it does not explain the interactions of internal human resources that provide the cognitive capability (Norman, 1988). Perceived affordance depends on representations in long term memory and the way the agent brain processes these. Secondly Norman's approach can confuse the perception of how objects and features of objects in the real world could be used by the agent, with our focus, the way knowledge can be used in the brain in terms of the affordance of reasoning and creativity to produce new ideas and thoughts (Albrechtsen, 2001). We therefore use the term cognition affordance to explain the possible interactions of mental resources that produce creative thought possibilities.

1.1 The Capability-affordance Model

Our previous papers introduced the idea of the capability resource model (Michell, 2011) and capability-affordance model using the work of Gibson and Norman. We reasoned that the capability of two interacting resources Ri was dependent on an affordance mechanism AM and the possible 4d space-time path AP to execute the affordance (Michell, 2013).

$$\text{Capability} = f(AM(Ri) \times AP(Ri)) \text{ and } R = f\{Aij\}$$

This was used to explain physical resource combinations or directly perceivable affordances acting in 3 dimensions plus time (Barentsen and Trettvik, 2002). However, we paid little attention to the way knowledge can be used in the brain to explain cognition affordance. We used Stamper et al. (2000) to differentiate between two types of behaviour substantive (or physical action) eg a doctor injecting a patient and semiological action of the doctor making sense of signs using his knowledge and cognition to diagnose the patient.

1.2 Definitions

Further details and explanations can be found in (Michell, 2013).

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Table 1: Definitions.

Term	Definition
Ri	A resource object in an environment
Aij	Affordance between resources I, j
C	Capability - the potential transformation of a system of resources = f(AMxAP)
AM	Affordance mechanism - the natural science of transformation
AP	Affordance path - the space-time interaction
Agent	Human/intelligent machine able to transform resources

1.3 Objectives

In this paper we explore how the capability-affordance model can be used to describe cognition and semiological actions with five objectives:

a) To set out the reasoning for semiological affordances and their relationship to cognitive affordances
b) To develop a model of semiological affordances and their relationship to existing work
c) To identify semiological mechanisms
d) To identify semiological paths
e) To account for creativity.

Section 2 explores the definition of cognitive affordance and its role in semiological resource interaction and defines cognitive capability as an interaction of agent cognitive and knowledge resources. Section 3 reviews cognitive resources using human cognitive behaviour. Section 4 reviews agent knowledge resources based on cognitive architecture research and identifies cognitive mechanisms based on semiotics models. Section 5 proposes an integrated cognition model. Section 6 discusses the implications of the model and Section 7 and 8 concludes and identifies future work.

2 SEMIOLOGICAL CAPABILITY

As mentioned before, this section considers cognitive affordance and its role in semiological resource interaction, and defines cognitive capability.

2.1 Cognitive vs Semiological

An action (a) is a transformation of resources (Michell, 2011). A semiological action uses signs perceived by the agent from the environment to process possible actions (Stamper et al., 2000) Semiological action depends on information and knowledge from sensors and cognitive actions in the mind of the agent. The interaction between the cognitive mechanisms of the brain and knowledge create possible ideas for action – cognition capabilities Ccog. Using the capability affordance model the cognitive affordance mechanism relates to the interaction of cognitive resources (Boy, 1998), one of which must be an agent's mind and its cognitive mechanisms Rcog. The second represents tangible or intangible resources ie data, information and Knowledge: Rk, obtained from the environment as only this is able to interact mentally in an affordance pair in the agent.

Ccog = f(agent cognitive mechanism x data, information, knowledge interaction) = f(Rcog x Rk)

To understand these affordances we need to understand theories of cognitive brain function. However, while the interaction mechanism of non-human objects is well understood, the mechanism of the brain is not.

2.2 Distributed Cognition Theory

Distributed cognition theory provides a framework for cognition spaces based on cognitive psychology (Zhang and Patel, 2006). We extend Zhang's model using a physical internal space Sp and a cognitive space Sc. Sp comprises the biochemistry and physiology resources of the body (B) ie the mechanism of biochemical reactions and the physical structures such as bone and flesh, synapses., muscle (P) that provide the path for the animal to work and select physical affordances. The cognitive space Sc comprises the mechanisms of perception and cognition (C) and the data information and knowledge (K) and relates to semiological affordances. The External space represents the environment and the natural and manmade (technology) structures (S) than provide physical and cognitive affordance possibilities as a result of agent sensor information (I) and actuators such as hands.

We now identify the agent cognition and knowledge resources and the mechanisms AMcog (C) and affordance paths APcog relating to data, information and knowledge (K) that enable semiological capability.

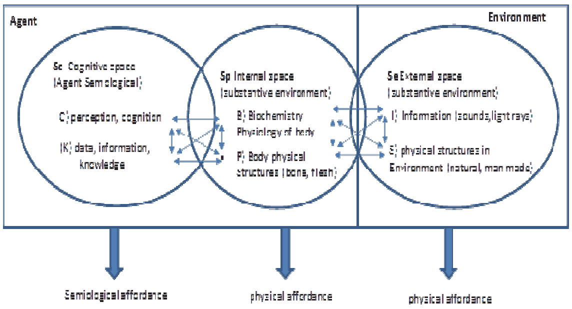

Figure 1: Affordance Spaces (adapted from Zhang).

3 AGENT COGNITIVE RESOURCES

3.1 Cognitive Behaviour Modelling

To develop an understanding of the cognition resources and their mechanisms AMcog we investigate applied psychology cognitive behaviour literature. Norman's 7 stages theory of action can be used to model cognition (Zachary et al., 1998). A worker will have specific goals G and actions to execute E to achieve them eg a surgeon examining a patient. This may involve a cascade of sub-goals eg visually examine patient talk to them, feel them. Perception P involves recognising patterns of speech, images from sensors and haptic patterns.

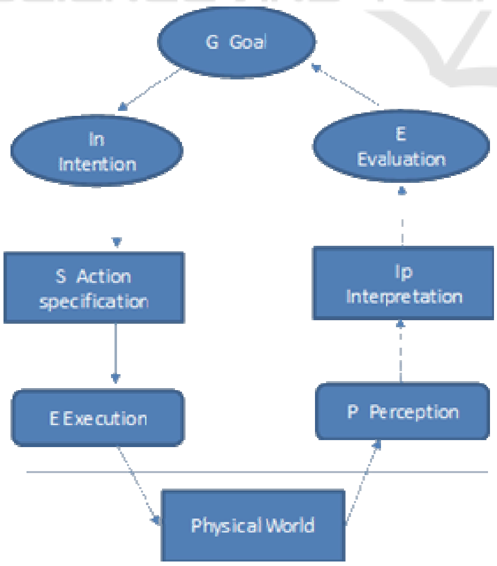

Figure 2: Norman's 7 Stages of Action (adapted).

The agent interprets the perception Ip in terms of how it relates to a planned course of action. The agent evaluates options for action E vs the goals and selects the best plan of action to achieve the goal. The user then plans his actions in his mind makes the intension In to act and specify the sensor-motor driving actions S. The agents actuators eg hands, limbs execute the action E. The result of the action is then perceived through the senses and compared to the goal and any corrective action applied. This P, Ip, E, G, In, S, E loop can be considered to be carried out at different levels of cognition.

3.2 The SRK Model

Rasmussen identified three types of cognitive behaviour in the skills, rules, knowledge in the SRK model of human decision making in high risk work-system domains (Rasmussen, 1983). Skill based behaviour corresponds to sensory motor performance during unconscious actions and unconscious control where the human sensor-motor system acts automatically based on the agents tacit knowledge of learnt tasks using learnt perceived patterns (Albrechtsen, 2001). Continuous 4d space-time data signals from agent sensors update a model of the environment in episodic memory. Skill based behaviour SBB relates to learnt sensory motor patterns based on previous experience, eg changing gear when driving etc and is termed unconscious control because of its automatic response directly from perception through the 7 stage model to sensor-motor action. Conscious control involves greater cognition using rule based behaviour RBB where recognition of signs and cues from the sensors drive an 'if-then rule' behaviour based on stored action rules related to cues perceived from the environment. This depends on perceptions of familiar patterns in a familiar environment matching the necessary cues/signs associated with the action rule conventions (Vicente and Rasmussen, 1992). Cues/signs relate either to experiences or learnt/cultural behaviour encoded as rules labelled for 'states/situation or goals and tasks' (Rasmussen, 1983). Rule based behaviour cannot generate new rules, but this occurs in highest level of behaviour, knowledge based behaviour KBB where the agent's mental model of the world enables the formulation of new rules, goals and strategies and predictions of the response of the environment. KBB can use both sensor and history information to construct the conceptual mental model (Albrechtsen, 2001). Rasmussen's SRK model identifies the three mechanisms of cognitive processing as data signals (SBB), as rules or cue-rule-action mappings or symbol/concept based problem solving and analysis actions (Vicente and Rasmussen, 1992).

Table 2: Cognitive tasks and actions.

	a) Miller's cognitive tasks and resources	
Ref	Cognitive agent task	Meaning
SE	Search	look for
ID	Identify	what is it/its name
CD	Code	tranlate in meaning
CM	Compute	identify logical/maths answer
CN	Control	adjust action to meet goal
PL	Plan	Matching resources to times
CT	Categorise	define/name a thing vs group
	b) Bloom's classification knowledge actions	
Ref	Cognitive Behaviour	Detail
RE	recall knowledge	recall information about concept or rule
CO	comprehend knowledge	understand the meaning of a concept or event
AP	apply knowledge	apply the concept/rule to a specific situation
AN	analyse	separate into concepts/parts to understand their structure
SN	Synthesise	assemble parts/concepts to form a new meaning
EV	Evaluation	make judgements about values and concepts
CR	Create	produce new knowledge and concepts

3.3 Cognitive Task Analysis

Work on analysis of cognitive tasks (CTA) for human computer interfaces (Hall et al., 1995) (Norman, 1986) and ecological interface design (Wong et al., 1998) provide additional models that relate to cognition. We use the convention of underlined letters as shorthand for cognitive tasks. Miller's vocabulary of actions for mental processes, human information processing resources and their related task agents (Lee and Sanquist, 1995), (Table 1a) represents the output of human cognition resources. Bloom's analysis of learning (Anderson et al., 2005) identifies cognitive behaviours related to cognition and learning. Recalling and remembering knowledge is considered the lowest cognitive level of activity that we can relate to SBB. With the action of comprehending or understanding knowledge at a higher level, that then enables the ability to apply the knowledge as rules and actions. The analysis activity is considered a higher level activity still with evaluate and finally create (new knowledge) and problem solving as the highest level of cognitive activities in terms of complexity and abstraction in the cognitive process. This relates to KBB (Table 1b), where cognitive tasks relate to transformation actions of agent mental cognition resources.

4 AGENT KNOWLEDGE RESOURCES

4.1 Cognitive Architectures

There are three main types of knowledge. Knowing what or 'learning by using relates' to the use of systems or technology as encoded in human episodic memory and can be loosely approximated to SBB. Knowledge from 'learning by doing' 'know how' corresponds to RBB (Carud, 1997). Rules are evident in the external environment as procedures, policies, processes and as tacit codified rules in agents. KBB relates to 'know why' or knowledge gained by 'learning by studying' as well as concepts and relationships and tacit mental models created in the mind (Carud, 1997). Cognitive architecture theories; SOAR, EPIC, ACT-R, PARI) (Laird et al, 1987), can provide insight into knowledge interaction. We use the COGNET knowledge framework (Zachary et al., 1998) based on cognitive psychology and goal oriented models based on Rasmussen's and Norman's approach (Figure 3).

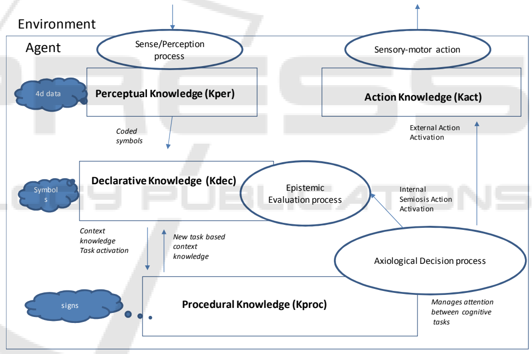

Figure 3: COGNET Knowledge Framework (adapted).

4.2 Perceptual Knowledge and Reasoning

In the COGNET model information from the agent's visual, aural haptic etc sensors is converted into 4d space time signal information. Sensory cues are perceived as visual (eg images) and auditory (eg conversation) patterns (Zachary et al, 1998). This sensory cue information in the form of signs becomes meaningful by the process of perception recognising patterns in the signals. COGNET uses the term 'sensory demons' to refer to system interface displays or patterns of natural phenomena eg a red spotted mole disease pattern. Auditory demons include speech terms and acts that have specific semantic significance. The interpretation of signs in the environment is the process of semiosis (Pierce, 1935) and a cognitive abduction process of inference to select the best semantic meaning of a sign eg for visual and aural recognition of patterns (Magnani and Bardone, 2006) as in perception related to a knowledge base of experience. In Pierce's process of semiosis, sensor signals for objects in the environment are perceived as signs and symbols representing objects and their meaning for the agent are decoded in a process of connotation (Benfell et al., 2013). The resulting perceptual knowledge Kper relates to pattern recognition models that link meaning to a visual model based on working memory and with experience from long term memory these provide 'coded symbols' that can be used by other cognitive processes.

4.3 Declarative Knowledge and Reasoning

Declarative knowledge, Kdec, includes the agent's mental conceptual model of the world based on the concepts identified through symbols and semantics mentioned earlier (Clark and Feldon, 2006) ie 'knowledge as a conceptual structural model' (Albrechtsen, 2001). It comprises abstract construct symbols which unlike rules cannot be reduced to signs (Rasmussen, 1983). It focuses on what and why and is based on propositions, facts and is hierarchically structured and uses episodic memory to record environment events and model them (Clark and Feldon 2006). The knowledge ranges from the real world ie 2D/3D models of the physical environment to logical relations and logic rules, facts, beliefs and solution strategies and cases to behavioural models and abstract models that have no equivalent in the real world environment. Declarative knowledge is used for problem solving and includes the history of relevant objects to the task and also plans and solution strategies to achieve a goal (Zachary et al., 1998). KBB relies on the individual tacit declarative mental model that the agent constructs that differs from agent to agent. Cognitive interpretation processes operate on the declarative model schema to make connections between symbols that enables insight and new knowledge to be developed to support problem solving. As Pirolli et al asserts Information=> schema=> insight=> solution (Pirolli and Card, 2005). The power, capability and reliability of agent KBB depends on the power, capability and reliability of the symbolic mental model and conceptual processing and related affordances. The range and complexity of declarative conceptual model covers predicates, definitions semantic relations (structural, causal, functions) and simple and complex associations as well as rules, facts and beliefs (Aamodt, 1991).

4.4 Procedural Knowledge and Reasoning

Procedural knowledge resources (Kproc) relates to models of rules, for example national language rules, job context rules eg clinical rules, mathematics rules etc. The rules are encoded with cues for when a task is relevant. Organisational semiotics models these rules in the form of norms (Stamper et al., 2000). The COGNET model suggests the goal and procedural knowledge form a cognitive task which directs the use of the knowledge through the cognitive mechanisms to execute a semiological or substantive task if the goal cue is recognised.

$$T_{cog} = f(\text{goal, procedural knowledge}) = f(G, K_{proc})$$

Cognitive tasks are managed at a meta-cognitive level of reasoning to decide which course of action to take and when to take it. These evaluation mechanisms are axiological mechanisms (Benfell et al., 2013) for decision making and selection of strategies related to agent internal resources affording decision making and evaluation. Meta-cognitive tasks adjust the priority of these tasks if interrupted by perceived events in the external environment eg bells ringing, 4d scene changes etc.

Interpretation Mechanisms. Reasoning involves interpreting information (sign/rule processing and symbols) about an environmental situation.

This could be from sensors and processing this information in conjunction with knowledge to produce a given goal. Reasoning may be rule based as in RBB. Sign/rule processing relates to the if-then reasoning using procedural knowledge ie selection of the best rule according to sign cues from the external environment. Alternatively it may be based on models and cases in the symbolic conceptual model as in KBB. Symbolic processing relates to the processing of symbols and read, write and update of the declarative knowledge model. This knowledge based processing capability unlike rule based processing is adaptive to new environments where new knowledge and rules can be developed by knowledge based reasoning (Albrechtsen, 2001). At higher level this involves processing mechanisms for inference methods. These methods may be deductive based on logical mental models and theories or inductive (knowledge of events and instances) developed from experience, education and training

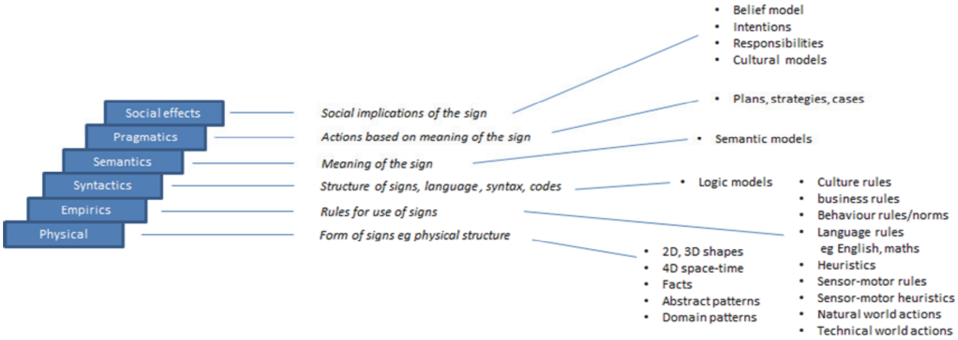

Figure 4: Semiotic knowledge hierarchy (after Stamper).

(Aamodt, 1991). Other forms of reasoning include induction and deduction based on neural connections made during learning these techniques from others. Deductive reasoning is based on logic models that may be learnt or culturally developed. Inductive reasoning involves testing against hypotheses.

4.5 Action Knowledge and Reasoning

Action relates to substantive action tasks on the technical or natural environment. For example, pressing buttons, moving objects. Alternatively they may relate to semiological actions such as communication (Zachary et al., 1998) or thinking that changes the state of the mind but has no external impact. Action knowledge relates to sensor-motor knowledge of how to drive and control the agent actuator bio-mechanics to control movement eg of hands/body. This relates to skills under automatic control in terms of hand-eye coordination driven by environmental cues for physical tasks. Action knowledge includes sensory-motor knowledge for natural objects as well as man-made technology eg hand-eye coordination for drug injection or routine mental maths calculations.

4.6 Knowledge Summary

We have seen an agent's knowledge covers a range of semiotic ladder levels. Rules and schemas may relate to the physical world. They may relate to use of language and the syntax for example sentence construction or mathematical expressions. They may relate to expected behaviour encoded from experience or business rules to cultural rules about behaviour. Rules may relate to formal models eg laws or they may be informal may be developed from experience, for example rules of thumb. Rules may relate to both physical and mental behaviours (Benfell et al., 2013). See Figure 4.

5 THE COGNITION-AFFORDANCE MODEL

Cognition affordance relates to a) the interaction of cognitive reasoning processes of the brain with knowledge to model potential actions and strategies for the real or imaginary agent world and b) the selection the best course of action either physical or mental. Cognition affordance depends on semiosis of perceived signs interpreted as sensor signals from the real world and/or from the conceptual world of the imagination of the agent using these signals, signs, symbols to model the real and imaginary worlds to plan actions. Cognition capability depends on the mechanism of cognitive tasks (Ct) acting on cognitive knowledge ie Ccog = f(Ct xCknow). The Cognition Model (figure 5) based on organisational semiotics EDA model (Liu et al., 2013) identifies and integrates cognitive processes in conjunction with the models discussed earlier.

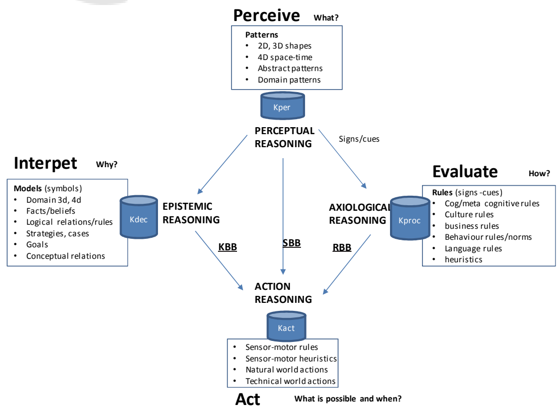

Figure 5: Cognition model.

Perception relates to pattern recognition reasoning on perception knowledge Kper. Epistemic reasoning relates to inference processes and reasoning about conceptual declarative knowledge Kdec. Axiological reasoning relates to rule based decisions about behaviour operating based on procedural knowledge Kproc. See Figure 5.

5.1 Perception Capability and Reasoning

Perceiving patterns in the environment relates to lower order cognitive tasks such as recalling RE and comprehending CO. This depends on matching perceptive knowledge ie the range of pattern databases the agent possesses or making sense of new patterns via epistemic reasoning. For example a clinician in seeking to identify a disease needs to match the cues from the patient in terms of visual/aural/haptic information after examining and talking with the patient and reading their notes. The clinician may build a perceptual model of the patient based on disease patterns, physiology patterns and models of consequences (Chapman et al., 2002). This produces a number of affordance options as possible disease models that need to be interpreted based on their plausibility relative to perception. This represents a cycle of Norman's model to meet the goal and intention of identifying the disease model for the patient.

Cper= f (perceptual reasoning tasks x Kper)

Audio perception is a function of the ability to both record and to match aural patterns sensed in the environment as a language of sounds with meaning. A language affordance eg 'can speak English' depends on the action of the cognitive processing resource recalling (RE) and matching information from the language patterns and the quality; depth, range of the agent vocabulary Klang.

Cper= f(Alang) = f(RE x Klang)

Similarly, visual perception affordances Avip are a function of the ability to both record and to match visual patterns sensed in the environment to meanings. For example visual perception affords recognition of disease patterns by recalling (RE) and comprehending (CO) disease patterns and cues that best match the sensed disease pattern which depends on the cognitive action of recall and its interaction with disease knowledge.

5.2 Interpretation Capability Cepi

Cepi - Epistemic reasoning involves higher cognitive tasks such as analysis AN, synthesis SN, problem solving PS and creativity CR as useful strategies in unfamiliar situations. Reasoning strategies such as induction, abduction and deduction may be used. The use of epistemic reasoning in medicine is often referred to as hypothetico-deductive reasoning (Chapman et al., 2002) and involves establishing a hypothesis for the problem illness, gathering data to support or refute the hypothesis followed be evaluation to establish the best causal reasoning (ie know why') for the symptoms. This requires conceptual knowledge models of illness, disease functionalities, mathematics etc. Affordance options relate to the different problem- solution models and their plausibility vs goal/evidence ie Cepi = f (prob solving reasoning x Kdec). The capability of epistemic reasoning as in expertise, is complex and in any individual will vary with the ability to reason and conceptually model the world and the depth, specificity and form of the knowledge the agent is able to develop (Aamodt, 1991).

5.3 Evaluation Capability Caxi

Caxi refers to: Axiological reasoning.

It relates to cognitive tasks using RBB and decision processes to select the best rule given environmental or mental cues. Affordance options here relate to the permutations of the possible meta-cognitive actions and their sequences and the cognitive task based are different rule models and their plausibility vs cues and the action goal.

Caxi = f (rule reasoning x Kproc)

Cognitive tasks relate to actions on procedural and declarative knowledge. Cognitive tasks include understanding and problem solving where obvious rules can't be invoked and declarative knowledge is required. This may include information processing strategies such as Miller's cognitive tasks planning PL and controlling CT (Lee and Sanquist, 1995). The rule evaluation takes place at different levels in the semiotic ladder. From the evaluation of laws and policy rules down to process and action rules. The rules act as a constraint on the possible actions. A clinician has many different rule sets to follow. At high level may be policies and WHO guidelines at the process level clinical pathways can be selected to guide possible team actions. At the action level algorithms (eg for inserting catheters) and the clinicians own heuristic rules developed from experience. The affordance options relate to different disease/illness rule models and the cognitive process involves the clinician deciding which rules to apply by assessing a series of permutations of cues and disease patterns.

5.4 Action Capabilities Cact

Action capabilities relate to automatic actions ie unconscious thought and skill based actions. This includes human-environment sensory motor skills eg grasping, human-technology skills eg using a mouse to drag and drop and human-human interactions eg shaking hands etc. A medical example might be identifying the actions and behaviours to stabilise an emergency patient (Chapman et al., 2002). Affordance options are different action models and their plausibility vs cue/stabilisation goal. Here the clinicians react instinctively to act based on experienced action knowledge of the steps to take how to behave and use equipment and human resources based on the cues for action from the patient, colleagues, technology resources and the situation ie Cact= f (action reasoning x Kact).

6 DISCUSSION

Cognition axes are proposed in this section as well as cognitive capabilities.

6.1 Cognition Axes: Real Vs Imaginary

We can say cognition capability is a tuple of these four capabilities:

Ccog = f (Cper, Cepi, Caxi, Cact)

In all the above cases the cognitive capability of the clinician will depend on experience, cognitive ability and cognitive resources. As Gibson notes: interpretation depends on the agents culture, experience and intentions (Benfell et al., 2013). The following sections discuss differences in cognitive capability. The agent cognitive affordance space Sc relates to how the mental models and reasoning process can provide the agent with alternative action possibilities. This represents the interaction of the cognitive reasoning mechanism resources with memory and knowledge. The axis of linkage between perception-action represents affordance possibilities in the real world of seeing and doing ie perceived and cognitive affordances. HCI design depends on making possibilities of using the technology as obvious as possible so they can directly be used for action. We suggest the linkage between interpretation and evaluation represents the imagination where possible concepts and possible actions can be modelled and the implications tested before action is decided. Another aspect of cognitive affordance is the possibility to imagine or model new imaginary interactions and imaginary logics and languages. Imagination suggests a conceptual environment that can model a) the real world and its features and use it to identify possible future states and secondly b) to model imaginary worlds with different rules, logic and beliefs. This capability enables great works of literary fiction (Harry Potter), art (Salvador Dali), science (relativity theory). Techniques such as brainstorming and creative methods where normal logic and beliefs are suspended can sometimes highlight new possibilities where the imaginary world highlights a new possibility or creative affordance applicable to real world logic. Perhaps the process of dreaming is nature's mechanism for trying out possible illogical affordances that would not have occurred to the conscious animal having to make sense of a real physical world!

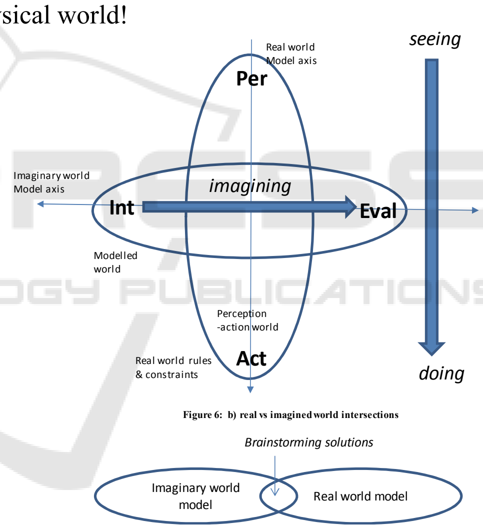

Figure 6: Cognition Axes – real vs. imaginary.

6.2 Comparing Cognitive Capabilities

Experience and practice in each of the cognitive mechanisms will be determined by the roles and work the agent carries out and how much involves real world vs imaginary world models. Some job roles involve a greater focus on seeing and doing eg a nurse, artist. Other roles focus more on imagination and conception without action as in the theoretical world eg novelist, scientist. Different roles will exercise and focus different cognitive functions. Some involve a combination eg a knee surgeon, may have good levels of perception of disease, 3d structures and have good haptic perception with much experience of manipulating joints. He may have lots of logic and problem solving experience, some experience of using clinical pathway rules, but will have less experience in policy rules and in reasoning about them compared to a Medical Director. An anaesthetist may have better abilities for reasoning about drugs based on repeated experience. In contrast an artist may be more creative than the surgeon because they focus their life on painting which involves seeing-doing action experience in terms of visual perception and painting heuristics. Their imagination is less structured and may involve creating and using imaginary rules and concepts. In contrast an architect's creativity will be more structured as it is limited by the rules of physics. Natural abilities to perceive, follow rules, to reason will also depend on the brain physiology as well as experience.

Ccog = f(Experience Ex x Reasoning Ability Ab)

6.3 Knowledge Paths

Knowledge is developed by the process of learning from experience and/or use of cognitive capabilities and mental modelling or taught or communicated by others. In each and every case both the knowledge and the cognitive capabilities is potentially growing depending on the brain physiology and individual cognitive capabilities ie intelligence of the individual. Benfell et al., (2013) mentions the link between affordance and memes in which affordances ie ideas are communicated 'by reading, watching television etc' It is this exposure to affordance examples that enables direct copying. Alternatively we may use our existing knowledge and cognitive skills to playing with and mutate ideas. We may use existing logic to extend our knowledge or, depending on our capabilities, create new logic to produce new knowledge. This happens at different levels of the semiotic ladder from the knowledge of the physical world through formal to informal abstractions such as culture knowledge with learned formal and or informal rules/heuristics. See Figure 7.

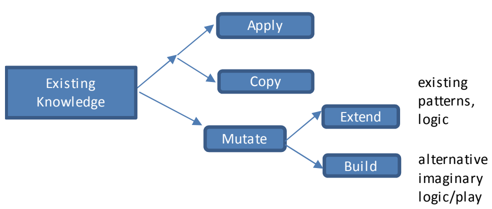

Figure 7: Knowledge paths.

7 SUMMARY AND CONCLUSIONS

This paper has shown how the capability-affordance model and others can provide an approach to explain the possible interactions of mental resources that produce creative thought possibilities and cognition affordances and meet our objectives. Section 2 explained the reasoning for semiological affordances by identifying the internal cognitive space and its relationship to cognitive affordance - objective a). To develop a model of semiological affordances (objective c) in Section 3 we identified cognition resources using the SRK model and cognitive task analysis. In section 4 we proposed agent knowledge resources based on cognition architecture and we suggested how semiotics and Peirce's model relate to cognition mechanisms. In section 5 we showed that Cognitive capability depends on cognitive functions interacting with knowledge and proposed 4 mechanisms for cognition. We proposed in section 6 that the cognitive path (objective d) depends on the knowledge paths where existing knowledge is applied and grown by copying or mutation. Mutation can occur as a result of mind games, mental playing and imagination. This mutation may use existing logic of Ccog to creative new knowledge directly applicable to the real world. or, to create new knowledge that is not directly applicable as theoretical knowledge. To account for creativity (objective e) we proposed how perceived and cognitive affordances relate to the perception-action axis and the epistemic-axiological axis relates to mental theoretical models to extend the real world model or create new imaginary worlds as in creativity.

8 FUTURE WORK

The complexity of cognition (the process of using cognitive actions and knowledge) means we have only scratched the surface. Further work is needed to identify the detailed mechanisms of cognitive affordance permutation with specific examples using cognitive task analysis. For example how does a novelist or artist think compared with a surgeon. However whilst methods such as Cognitive task analysis can provide useful insights into the processual mechanisms, the detailed models rely on developments in cognitive psychology and medical research.

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