Exploring the Relationship Between the Processes of Abstraction and Creativity

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by

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CERTIFICATE

It is certified that the work contained in this thesis, titled "Concept Content and Creativity" by Vanalata Bulusu, has been carried out under my supervision and is not submitted elsewhere for a degree.

Date	Adviser: Dr. Priyanka Srivastava

To the grandfather I never had,

Thank you.

To my Boos,

Gop gop.

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Abstract

Making things, coming up with strange new ideas is what creativity is. The question of where these *new* ideas come from is the very question that drives all study of creativity. Creativity has to come from the knowledge that exists in the minds of the creator [1]. This work participates in the questions of how we come up with new ideas and to what extent the conceptual space influences creativity. We form concepts through the process of abstraction. Despite having been long established that creativity does not come from the Gods but from our mental and bodily processes, there is very little work on the processes of concept acquisition. There is almost no work that directly studies creativity and abstraction together. This work argues that creativity research assumes an Amodal Symbol cognition structure where the processes of cognition and higher cognitive functions are not related. As a result this relationship has not been explored. This work employs a mixed method approach, using both qualitative and quantitative methods for coding and analysis of abstractions and creative generations. A wordlist based on familiarity, level of abstractness and modality experience was created. A norming study of the rating of abstractness of these words showed significant variability in ratings indicating subjectivity in the perception of abstractness. To study abstractness and creativity a Property Generation and an Alternate Uses task was conducted. Traditional theories of creativity assume we manipulate taxonomic or entity properties in a computer like way, during the process of creativity, however our results emphasises the role of individual experiences in the process of creativity.

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Chapter 1

Introduction

Concepts are simultaneously deeply personal and at the same time nonchalantly used in everyday, mundane conversation assuming a common understanding. But, how do we know that each of us has the same understanding of the concepts we use even if we act as if we do. Frege's theory of sense and reference differentiates between an individual's understanding, which he calls the ”sense” and the concept which he calls the ”reference” [2]. For example, the concept ”gold” used by a scientist could contain the atomic number 79, extraction and the use of Gold and its material properties. The concept ”gold” used by a painter could contain connotations of ”gold”, like decadence, wealth and royalty. The same concept or ”reference” has different senses for different people depending on their experiences.

How are these concepts like cup, door, knob, cycle, run, cry, and freedom, justice, happiness and warmth formed and experienced? Does the formation of concepts evolve with our ability and experience of perceptuomotor interactions with the world or is it independent of our bodily experience of the world? What happens when one of our senses is shutdown or not functional, thus, depriving the sensorimotor feedback for corresponding actions? For example, would visually impaired individuals construe a visually dominant world differently from sighted individuals?

According to the embodied paradigm, the sensorimotor interface with objects in the environment makes the construal of concepts easier but leaves scope for differences in the way we interact with it. Would differences in experience with each of these entities result in different meanings to the individual? Studies have shown the importance of active and passive interaction in conceptualization of concepts like spatial relationships [3], or experiential learning on concrete and abstract concept formation [4][5]. Most importantly, the grounded theory of cognition argues that the sensorimotor experience is not only important for the concrete representation but may also play an important role in abstract concept formation, like freedom or happiness or spatial knowledge.

For example, let us look at the concept ”chair,” the representation of it may constitute the structural (four legs, with a seat, there may be hand-rest and backrest), functional (seating and resting), situational (used for dinner, games, fun and dance), taxonomical (e.g. furniture, bean bag), introspective (bean bags are comfortable, I miss the chairs we had in 8th grade) and more abstract associations like chairperson, power politics for chair etc. It is interesting to think that that despite sharing the similar functions, seating and resting, the chair, stool, and beanbag are different concepts with different connotations and different concept content for different people. So, what comes to mind when we hear these three different concepts, like chair, stool, and beanbag? Would these be equally and strongly associated with the properties like chairperson or power or power politics? Why is it the case that we associate the traditional chair with power but not the non-traditional beanbag? Further, how are freedom and justice defined and represented by the individuals who have experienced or are experiencing slavery? How would ”discrimination” be defined by an individual who has experienced discrimination of any form than someone who did not?

The basic unit of knowledge are concepts [6][7][8][9]. We get all information about the world from our senses. There are two competing theories of concept representation. The first: Amodal Theory claims that all sensory experience is converted into abstract symbols and stored. We use these symbols to reason and compute on. The other theory: Embodied theory claims that our concepts are made of direct perceptual experience. This fundamental difference in representation results in differences in the cognitive architecture of our concept representation.

1.1 Theories of Concept Representation

There are two major competing theories of concept representation: The Amodal Theory and the Embodied Theories (also called Grounded Theories). They differ on the structure of cognition, the form of representation and how information from bodily organs is dealt with. The Amodal group of Theories broadly claim that information is received through our sense organs which is converted and stored as symbols. The Embodied group of Theories claim that our bodily sensorimotor interaction with the world form the basis of our concepts. Both of these are groups of theories with several postulated models based on which cognition structure the models ascribe to.

1.1.1 Amodal Theory

The Amodal Symbols system claims that all the information received through our sense organs are converted and represented as symbols. Like binary code or icons [10] or words as symbols [11]. These symbols bear no resemblance to our perceptions [12][13]. This means that the symbol, or set of symbols representing ”tomato” do not look like a tomato, have no similarity, isomorphism or homologousness to a tomato. It is arbitrary and could as easily be used to represent ”jellyfish” without any conflict with our perceptuomotor experience. But, due to particular internal structures in our brain responsible for the conversion from sense information to symbols, called transduction, it represents ”tomato.”

This system believes the human brain to be made up of discrete parts that work independently. In this model, the five sense organs are the source of inputs, various modules in the brain perform processing and higher cognitive functions on these inputs and the outputs are either stored or spoken or acted on by separate systems of storage and motor movements. Susan Hurley calls this the sandwich model, where,

”the mind is kind of a sandwich and cognition is the filling” [14]. This system sees perception and action as two separate things. It sees all parts as modular and cognition as a linear process from perception to action. This partakes in the Descartian mind-body dichotomy framework [15] or a computational view of software residing on hardware [12][16][9][17].

The classical Amodal symbol system model draws from Turing and Von Neuman machines [18]. All computation, is performed on symbols. This system claims advantages in terms of representing propositions, computation power [19]. But what do these systems look like? Proposed implementations of this system include propositional networks [20], feature list and hierarchical trees. [12]. These predict that our conceptual knowledge consists of a list of features and taxonomic properties. Feature lists have place holders like variables in a dataframe, which are filled in through our experience of the world. It promotes an objective understanding of all concepts, like a compendium of definitions similar to the standard Oxford Dictionary sitting on our bookshelves.

Criticism to this theory asks for more explicit explanations for the processes during transduction [12][21][6].

1.1.2 Embodied Theory

The Embodied theory, also called Grounded Theory proposes that our concepts are represented in sense information [22][23]. The most popular model for this is Barsalou’s Perceptual Simulation Model [21] which draws on experiments in mental imagery [24] and mirror neurons [25] to claim that concepts are partial re-enactments of what we experience. According to this model, there are neuron distributions in the perceptual processing areas in our brain which get activated on receiving perceptual signals. When we think about concepts, these neurons fire up in partial patterns to perception patterns.

The implication of this theory is that our interaction with the world in terms of perception and action plays a fundamental role in shaping our conceptual framework and content. Concepts are shaped by our individual experiences in our individual surroundings. The concept of ”cat” is not just four legs, retractable claws, but it consists of the ”neighbour’s cat I played with in her house in the afternoons after school.” All of this is part of the concept of ”cat.” According to Barsalou, ”the idea of road is probably more a part of the idea of car than the chassis itself.” [21] The Grounded theories ground concepts in situations and our internal mental and affective states.

1.2 Creativity and Abstraction

These two theories have differences in how these concepts once acquired are ”computed” or ”used.” Higher cognitive functions like creativity, reasoning, language work upon concepts for their functions. While, clearly concepts and the content are important to these functions, how they are used and manipulated needs to be studied and formalised.

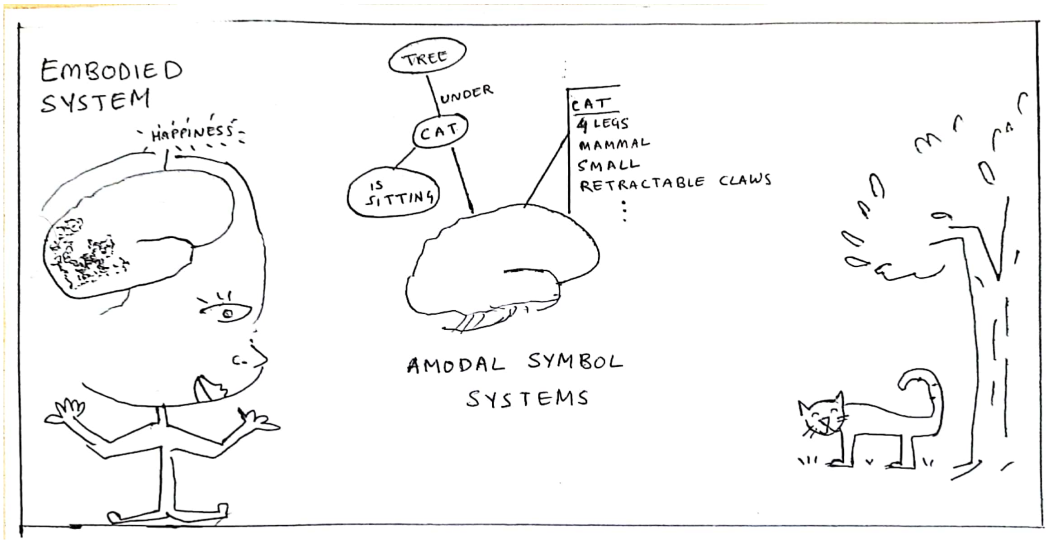

Figure 1.1 Illustration of examples of modal and amodal systems of representation, representing a scene of a cat under a tree (right corner). Amodal Symbol systems use feature lists of proposition networks (middle). It views brain as separate from the body. Embodied systems use sense information to represent concepts (left). The whole scene and not dissected parts are represented. The kind of body will affect interaction and therefore, concept structure and representation in embodied systems. Here, the body is not to scale and only an artists impression to show the brain situated in a body.

Creativity comes from existing knowledge in our brain [1][26]. This knowledge is stored using concepts. Therefore, "our understanding of creativity cannot be complete without a detailed and rigorous treatment of the cognitive preprocesses from which the novel ideas emerge" [27]. If the content of concepts are different for different people, and if creativity comes from individual existing concepts, then how does this difference manifest in creativity? Say, for a congenitally blind person, their world is serial, they experience their world through touching the world one by one. For a sighted person the world in simultaneous, we see the fish in front of us and the other people at dinner all at once. How or would this difference in experience result in differences in creativity.

According to the embodied paradigm concepts are very individual and subjective whereas the Amodal system sees concepts as more analytical and abstract. How do these two different systems model the process of going from existing concepts to creative generations. However, there is surprisingly little work studying conceptual knowledge and creativity [28][29]. Part of the reason for this gap lies in the history of creativity research which is elaborated upon in Chapter 2.

Concepts are formed through a process of abstraction. Therefore, to fully understand the process of creativity, the process of acquisition also needs to be studied and understood. How do we go from concepts to creativity which is forming new knowledge and new concepts from old knowledge? What is the relationship between the two? What does an embodied creativity look like? These are some of the questions that motivate this work.

1.3 The Rest of the Chapters

This thesis studies the relationship between creativity and conceptual knowledge. We are particularly interested in modality specific processing and abstraction. Chapter 2 outlines the definition and measures used in Creativity research. It argues that creativity been has studied assuming Amodal systems. It shows how this assumption has influenced the constructs of creativity and directed its research. Chapters 3 and 4 present the experiment and data. Since the study required considerable preparation, it was divided in two parts. Chapter 3 discusses the perception of abstractness and concreteness. This has been a prominent debate between the two theories of concept representation. It presents a pilot rating study which was used for norming. Chapter 4 outlines the interplay between creativity and abstraction as an under researched area, despite frequent acknowledgement of its role in the mechanisms underlying creativity. It presents the experiment studying concept content and creativity.

1.4 Pandemic Woes

This work was originally intended to be a comparative study of conceptual knowledge in sighted and congenitally blind people. When one modality is absent what does this mean for conceptual understanding and therefore creativity. Neuroscience, psychology and cognitive science have always had a fascination for the weird, abnormal and ”sick” [30]. Studying these ”anamolies” not just illuminate these ”abnormal” processings, but also recognises the immense complexity in ourselves. These ”freaks” help us ask questions about human processing itself, that because of their ”obviousness,” we would not have otherwise asked. Unfortunately, we could not carry out this study due to an untimely freak of disease.

We had planned to use haptic stimuli: small 3-D printed models of objects for our blind participants and parallel haptic and visual stimuli for our sighted participants. However, the first wave of the Pandemic made touch as a stimulus for the study obsolete. Like researchers everywhere, we modified our study to a completely remote, online version. By the time we re-situated our hypotheses and readied our experiment, we were met with a second dose of even worse death and devastation. We were informed that a lot of the blind patients at LVPEI (L. V. Prasad Eye Institute), the hospital we were working with, had lost family members close to them and would be unavailable for data collection for all research projects. This forced us to cancel this part of the study altogether.

While this study is not as we had intended and the remote nature of the experiment presented its own challenges in terms of technical difficulties and network mishaps, our questions broadly remain the same. The idea that modality can play a significant role in shaping our concepts and creativity excites us.

Chapter 2

History of Creativity Research: Definitions, Measures and Assumptions

Creativity is a relatively new word in the history of human thought. It's first recorded use was only in 1875 [31]. Before this, the idea of human creativity did not exist. Creation only belonged to God. A God or a divine power could *create*, and people acted on the ideas *given* to them or *discovered* the underlying rules of his perfect creation. The Greek called it *poiesis*, or 'coming into being', or 'discovering a truth'. Newton, who's mechanical Laws of Motion is considered one of the most creative theories in human history, considered his laws as discovering the underlying rules set by God. Ramanujan, an Indian Mathematician had attributed his intuition to his village Goddess Namagiri [32]. The idea of human agency in creating new knowledge came about only during the late 1800s. The shift of creation belonging to an all knowing entity to being situated in human faculties demanded an explanation of creativity in terms of human cognitive mechanisms.

The Enlightenment era saw science and technology develop at a rapid pace. Scientific inventions and discoveries were made from systematic observation and human reasoning, not God. Man was making things based on ideas and principles developed by other men. The Spinning Jenny, Aeroplanes, automobiles all were a result of the power of human reasoning. With technology having such a significant impact on human lives, our understanding of knowledge acquisition shifted from Gods to human processes. Specifically, "reasoning" was heralded as the human cognitive faculty that made creation and with it, advancement possible. Reasoning and rationality became enmeshed with the idea of creativity. Ideas from divinity and the industrial revolution have influenced creativity research and its assumptions.

This chapter will outline the definitions, measures, assumptions and "messiness" of studying creativity cognitively. It will show that traditional creativity research largely assumes an amodal architecture. An Amodal architecture assumes that perceptuo-motor systems, memory and creative functions operate modularly i.e. separately and independently of each other. This amodal assumption has led to the various aspects of knowledge acquisition and creativity: perceptuo-motor systems, memory, retrieval, convergent thinking, divergent thinking and combinations being studied independently of each other.

2.1 Definition

Creativity has been notoriously difficult to define. The creative outcomes or products span across material objects, ideas, to art performances. The skills employed vary across domains. Further, judgements of what is creative are "inevitably subjective and dependent on culture and historical period" [33]. Given how broad the scope is, it is not surprising that a significant portion of initial creativity research focused on defining creativity. To be able to study cognitive processes meaningfully, a clear construct definition is required. A broad consensus on the definition of creativity falls in two parts: originality and "value."

Here, it is to be noted that creativity is used interchangeably in literature for both product and process [34][35]. This is partly due to the initial confusion about how to define this and the various views surrounding it. This thesis will refer to all outcomes as creative outcomes or creative generations. The underlying mechanisms will be referred to as creative processes. "Creativity" will refer to the field at large.

2.1.1 Originality

Originality, (generally defined) is how *new* a creative outcome is considered to be. This *newness* has been a crux of tension in creativity research. What does "newness" mean? How can something be completely new when all creative outcomes are but transformations of existing knowledge?

The first views held that truly "original" outcomes are unheard of, unexpected, cannot be analysed using existing structures of knowledge and are unrelated to past knowledge [36][37]. They considered originality as necessarily independent of existing knowledge, because originality had to be something that did not exist before.

To explain this, the process of creativity was seen as an instantaneous process without explicit intentional agency of the creator. Kant wrote [38] that the process is not a series of mental functions but rather an "inexplicable" and instantaneous process where "he does not himself know how the ideas for it have entered into his head, nor has he it in his power to invent the like at pleasure, or methodically". According to Schopenhauer, the abstract concepts that exist in our mind constrain the otherwise organic creative process happening to us, or "nature plucking on our cognitive harp strings" [39]. He, like Plato saw creativity as a result of madness characterised by, " a case of the thread of memory being broken, its continuous connection being abolished, and of the impossibility of a uniformly coherent connection with the past"[40]. Similar accounts in creativity literature appear while discussing the "ah-ha" moment or insight, where the generation is a sudden realisation. The instantneity of this process allows this theory to keep a linear model, where previous processes are not involved and do not shape the later higher cognitive processing.

This way the existing concept space plays no role on the new generations. The implication of such an understanding of originality is that all generations are equally likely and all people are equally likely to come up with all generations. This implies that creativity is independent of demographic. Experience and existing knowledge do not play a role in creativity. In fact, experience is generally considered to play an inhibitory role in creativity [36][41].

2.1.2 Value

Originality is not a sufficient criteria for creativity. If creativity were only characterised by newness, a random string of words never seen before would be some of the most creative generations ever made. This distinction is particularly relevant in this age of technology, where we distinguish between computational generations and human generations.

Creativity is therefore characterised by as second parameter: *value*. That is, an outcome has to be original and valuable in some way to be called creative. Value has been defined in many different ways. It has been called ”effectiveness” [42], ”beauty,” but most often this part of the definition is defined as ”usefulness.” The first print of the Creativity Research Journal referred to this as ”utility” [42]. As Piffer [33] points out, ”usefulness” does not capture the *value* associated with artistic creativity. Art is neither a utility item nor is it meant to be ”useful” like a pencil is meant to be useful. The idea of creativity emerging during the Industrial Revolution probably shaped this notion of ”value” in terms of ”utility,” during a time that looked in awe at the large scare production of utility items and the significant impact it had on all aspects of human life. This mechanistic view that was prevalent at the time not just shaped what we see as valuable, but how the processes looked like.

2.2 Creativity and Intelligence

Creativity research arguably began with Dr. J. P. Guilford, who was then the President of the American Psychological Association. For his Presidential Address he chose creativity. This first theory of creativity comes out of a factor analysis of intelligence. ”Factors may be classified according to: basic processes or operations (cognition, memory, convergent thinking, divergent thinking, evaluation), material or content (figural, symbolic, semantic), products (units, classes, relations, systems, transformations, implications)” [43]. Here, the brain is seen as a modular structure. Different operations, materials and products are all neatly separate factors, each having its own distinct function where interaction between these structures is limited. The memory is separate from the processes that are performed over it, there is an input output system with specifically characterised outputs. Further, all the outputs characterised by this system are analytical objects.

The models of intelligence saw the brain as an amodal symbol system, and by extension creativity research assumed amodality in its structure. Intelligence research was heavily shaped by the then advancements in logic, mathematics, computers and technology [44][31]. The idea of reasoning itself has a basis in the advancement of technology, where the scientific creativity that led to economic and social development [45] comes from logic and reasoning. The brain was regarded as a computaion device, or a ”Turing machine” or ”automaton” [18][46]. The processes in the brain are processes of computation. This allows a ”powerful” symbol system. The amodal symbol system sandwich can implement type-token distinction, explain prepositions and productivity [19][18].

In this way, creativity assumes a structure that is similar to a computer and is based in symbolic representation. of the brain while speaking of the processing that underlie creativity. With emerging evidence for interconnected and interdependent systems, there is a need to examine creativity from a different framework.

2.3 Implications of the Amodal Views on Creativity

If generations are a process of random selection then all generations are equally likely. A more conservative view on creative generations holds that if generations are random and independent of existing knowledge, then all people are equally likely to come up with all generations irrespective of culture, gender, class etc.

Another view on individuals and the generation of creative outcomes sees generation as a mysterious and instantaneous process. A mark of genius, ”giftedness,” or the ”a-ha moment” [1][27]. According to Kant, ”genius is the innate mental aptitude (*ingenium*) through which nature gives the rule to art” [38]. Here, the creative process is *given* from outside the mind by ”nature” instead of a God. The individual is gifted from birth and the process is not a series of mental functions but rather an ”inexplicable” and instantaneous process where ”he does not himself know how the ideas for it have entered into his head, nor has he it in his power to invent the like at pleasure, or methodically”[38]. Creativity does not depend on an individual’s conceptual knowledge, creative people, rather, ”genius,” and the ability to be creative is delineated by ”nature” from birth [47][27].

For example, we can see this in the theories of creativity like the Geneplore Model [48], or Blind Variation [49]. These theories essentially postulate that generation of creative outcomes involves a random process similar to Darwin’s random selection. This randomness disregards any structures that exist in the conceptual space as well as intentionality of individuals while moving around their conceptual space.

2.4 Creativity and Abstraction

An Amodal architecture sees the process of sensing, processes of concept formation and the process of creativity are separate processes that occur independently of each other. According to this system, we perceive things in our environment and abstract these into sets of symbols that represent these things. Creativity is a function that is applied over these abstracted symbol space. Since these three processes are distinct and independent, there was no need, moreover it was senseless to study these processes together. An Amodal architecture focused on figuring out which functions are performed over a static concept space of sets of symbols. As discussed in 2.1.1 the symbol space does not shape or influence the processes of creativity beyond the quantity of information that is present about each subject i.e.

someone with more facts about cat diet will have more ideas to manipulate than someone who does not know as much about cat diet.

The process of forming concepts is referred to as abstraction. The idea of abstraction according to a metaphysics based on a God is one of being able to know ”essences” or ”perfect concepts” from an *a priori* set of knowable, determined concepts that have been decided at the beginning of time when God created the world [50]. This means that there is an objective knowable concept and everyone should know it in the same way. This idea of objectivity in how we understand the world can still be seen in more contemporary understandings of concepts and abstraction. Amodal Feature lists postulate lists of features in terms of specific quality markers like colour, height, weight, number etc.[20][44] This implies that when one abstracts from sensory information, we abstract the qualities and properties, which are equally knowable i.e. abstractable to everybody. In this way, all solutions are equally likely and every individual is equally likely and unlikely to come up with a particular solution. However, there are differences between any two people, everyone comes up with different generations. Traditional theories of creativity explain these differences in terms of genius and personalities. More recent embodied theories instead emphasise the role of experience through the sensorimotor system.

The embodied paradigm does not just explain individual differences, but proposes a fundamental difference in how cognitive functioning is viewed and therefore how creativity and abstraction are imagined. [51][52][12]. Embodied theories base the cognitive system on sensorimotor interaction with the world. The systems involved in perception cross-talk with the systems of representation, the systems involved in creativity and systems involved in output. The representation systems uses direct sensori-information for representation rather than abstracted symbols [53][44]. The embodied paradigm has gained prominence in the last couple of years, so, while there are theories on categorisation and concept representation, there is not as much study on what higher cognitive functions look like. More study is needed to understand the interactions between the mechanisms and to what extent they influence each other.

Representation directly in terms of sense experience raises the question of what abstraction looks like in an embodied paradigm, what a gradation of higher and lower levels of abstractions mean. If all concepts are made of our direct sensory experience, for example, the concept of cat is literally a collection of all the cats we have come across, then there is no abstraction that takes place, but concepts are just a collection of experiences. One of the explanations for this is Barsalou’s partial re-enactment, where not the entire experience is re-enacted, but a part of it, like the colour or touch of your best friend’s Siamese cat [12][21][6]. Another is Rosch’s Prototype Theory, where concepts are based in real world exemplars and new objects are identified based on how similar they are to the examples [54][53][55]. One can identify a Siamese cat as a cat because it looks like what we learnt as cat.

Concepts are fundamentally subjective. Rosch (1999) wrote, ”the world does contain “intrinsically separate things. The world is structured because real-world attributes do not occur independently of each other. Creatures with feathers are more likely also to have wings than creatures with fur, and objects with the visual appearance of chairs are more likely to have functional sit-on-ableness than objects with the appearance of cats" [53]. This implies that our concepts are moulded by the world we are born into and our concept space is specifically structured to make sense of our specific contexts. This is in contrast to the amodal system which postulates a model of objective reality independent of individual contexts: gender, place of birth, culture, race and education. Whereas, the Embodied theories consider emotions, cultural beliefs and attitudes as integral parts of concepts. These differences in the imagination of the processes underlying creativity will inadvertently shape how it is studied and understood. The formalisation of an embodied model of creativity proposes a new imagination to an otherwise linear, mechanised creativity process.

Similar to abstraction, creativity is not directly explainable by embodied assumptions. Combinations, transformation, searching and generation requires explanations beyond direct enactment. How do *re-enactments* result in new knowledge? This requires some explanation in terms of abstractions. But which parts are chosen to be abstracted and how are new generations made? These are questions that do not have concrete ideas yet, which makes this area very exciting. This problem with creativity, the problem of explaining this function in terms of sensorimotor systems is not just about creativity, but about all higher cognitive functions like reasoning.

Therefore, it only makes sense to study abstraction and creativity together. If the embodied theories are correct, then abstraction should influence creativity. Understanding this relationship not only helps us understand the mechanisms underlying creativity, but understanding our cognitive system itself.

Chapter 3

Abstractness: Norming and the Perception of Abstractness

Vocabulary has words such as ”apple” and words such as ”democracy.” Intuitively, democracy is more complex than apple, you could expect a toddler to blabber and point and know apple, but one would hardly expect them to point and scream, ”Democracy!” In Elementary school, words like ”apple” are called common nouns and ”democracy” as abstract nouns. Coming up with these complicated words is peculiarly characteristic of humans. It allows us to think of ”capital” and ”secular,” which allows us to imagine complicated social relations. What are the processes in our brain that make this possible? Is there a cognitive basis for this distinction? Do common nouns and abstract nouns use the same mechanisms or do they use separate mechanisms? Classical theories postulate separate, differentiable mechanisms for processing abstract and concrete words [56][57][58][59]. According to these theories, abstract and concrete words form a non intersecting binary based on physical referencing. Concrete words have single material referents in the world, whereas abstract words do not have material referents. An alternate group of theories suggest overlapping mechanisms without a clear, fixed distinction. They suggest that both kinds of concepts are grounded in sensory-motor information, where concrete words have a higher percentage of direct sensory-motor grounding than abstract words. Along with physical referents, both concepts are grounded in experience, situation knowledge [21][6], emotions, social cognition, internal and mental states [60][6][61][7]. This means that while abstract words and concrete words have different ratios of grounding areas they are both represented by the same mechanisms resulting in a spectrum view of abstractness and concreteness.

Work in the Embodied Paradigm has led to a resurgence of studies on abstractness and concreteness and how our cognitive systems handle these concepts. There is debate as to whether they are binary or a spectrum, and whether the same cognitive mechanisms are involved to different extents or different cognitive mechanisms are involved in their processing [21] [62] [63] [9] [6].

The definitions that exist in literature define these constructs on the basis of different properties. The definitions of abstract and concrete can be broadly categorised into 3 types:

1. Abstract and concrete defined on difference in representations. Paivio [64][20] distinguished concrete concepts as being represented by visual as well as verbal representations. Whereas, abstract concepts are represented only using verbal representations. There is also recent evidence

from Mahon and Caramazza [65] supporting this claim. This definition implies a strict binary between abstract and concrete concepts. Also, that they are treated distinctly differently by our cognitive mechanisms. This further implies that all people would mark the same words as abstract or concrete.

2. Abstractness defined by a lack of perceivable features or physicality. This definition is also referred to as the Classical Definition of abstractness and concreteness. [9] [12][13][14]. According to this definition the level of abstractness is given by the extent to which the properties or the concept itself is perceivable through our senses. For example apple has colour, shape, weight, taste, it is countable, it makes a "scrunch" noise when you bite it. All these are directly perceivable qualities. Whereas, "truth" does not have a specific visual, tactile, auditory, olfactory, gustatory or even motor quality. Therefore, apple is highly concrete and truth is highly abstract. It is unclear whether, this definition sees abstract and concrete as binaries or as a spectrum. Linguistically, abstract nouns (characterised by their non-physicality) and concrete nouns (characterised by physical objects) are considered two distinct classes of nouns with no intersections. However "lack" can also be understood as the extent of lacking, where abstract concepts are highly lacking in perceivable qualities and concrete concepts have a lot of perceivable features [9][66].

3. Abstractness defined on multiplicity of referents. The level of abstractness is defined on how many objects or concepts the superordinate concept subsumes [28].

One of the reasons for this difficulty in defining abstractness, is the wide range of abstract concepts: from emotions to concepts such as "justice" and "liberty" to numbers [16][62]. One of the recommendations is that abstractness be studied type-wise. Borghi et. al. [7] proposed 4 types of abstract concepts: i) emotions ii) numbers iii) morality and aesthetics and iv) social-cultural abstract concepts. These concepts are grounded in i) perceptuomotor systems ii) social interactions iii) introspection and internal mental states and iv) language.

The questions about the differences in experience stemming from different dominant modalities as modes of experience for sighted and congenitally blind systems, motivates this investigation. "Perceivable" and "physicality" are not the same for sighted and blind people. A lot of things perceivable to us through our vision are not perceivable to blind people. Colours, aeroplanes (objects which are difficult to access through touch), wild animals and height of a sky scraper are all things routinely perceivable to us and very concrete according to the established definitions. Do blind people treat these as concrete or abstract? Is the understanding that these are technically "perceivable" enough for the understanding of concrete - abstract and is there a difference in brain mechanisms?

If the classical definitions are robust enough there should be very little variance in abstractness ratings. The second interest of the investigation is modality specificity in abstractness ratings. Does the modality dominance of a word (the extent to which a word is perceived through that modality) have any effect on abstractness?

3.0.1 This chapter

To study abstractness and concreteness we need abstract and concrete words. This chapter is divided into two parts. The first section describes the process of creating a wordlist, selecting words from three publicly available datasets. The second part of this chapter will describe the experiment for collecting ratings of the perception of abstractness and present some preliminary analysis.

Concept representation has largely been studied through recall and memory tasks, semantic analysis of Property Generation Tasks, language and neuroimaging of comprehension. There are relatively few studies which directly ask participants to rate words on abstractness and concreteness using the Classical definition. These studies have found that abstract and concrete have significant differences between them, but contain significant variation within the clusters (Wiemer-Hastings et. al., 2001; Harpainter et. al., 2018). This work will also examine i) the variance between concepts ii) conducts a cross cultural comparison of the perception of abstractness.

3.1 Stimuli

To study abstractness, a list of words was curated.

As discussed in Section 1.4, the study was originally designed as a between congenitally blind (people who are blind from birth) and sighted people investigation. The stimulus mentioned in this chapter were selected keeping both populations in mind.

The visual modality which is considered the dominant modality for a sighted person is inaccessible to the congenitally blind population. Congenitally blind people primarily use tactile and auditory modalities as their dominant modalities [67] for interacting with the environment, instead. If experience plays a vital role in the formation of conceptual knowledge, then the way in which one interacts with the world should affect ones's conceptual knowledge. This makes an interesting case for studying the role of modality specific experience in conceptual knowledge. What role, if at all, does modality specific experience play in the kind of abstractions we make? Do the affordances that each modality offers direct certain kinds of abstractions more often than others? Auditory, tactile and visual modalities were chosen taking into account the natural dominant modalities for the two groups we were interested in studying. The last parameter: modality dominance, was of particular interest to us for studying qualitative differences between congenitally blind and sighted participants.

Words were selected based on three parameters:

i. **Familiarity.** The extent to which a word is familiar for most people. Familiarity is taken to be a measure of how comfortable one is with a given word, how easily it can be explained and how often it is used or heard of by the individual. Words with high familiarity were chosen.

ii. **Abstractness.** This is the extent to which a word and its properties can be perceived through our five senses [9]. The extent to which the word is situated in a perceptible referent. For example ”red,” ”stinky,” ”slimy” are highly concrete and ”joy,” ”truth” and ”democracy” are highly abstract.

iii. **Modality Dominance.** This is the extent to which a word is perceived primarily through one modality. Words that were modality dominant in Visual, Tactile and Auditory modalities were chosen.

The words were taken from three publicly available datasets. The datasets and their aims are briefly described below:

1. **van Dantzig et. al.(2011)** [68] contains modality exclusivity scores for properties and common nouns. Modality exclusivity is the degree to which a property is perceived exclusively through one sensory modality. For example, the property ”sharp” is perceived more through the tactile modality than any other modality. Van Dantzig et. al presented each property in two contexts, e.g. ”sharp knife” and ”sharp image.” Participants were asked to rate ”the extent to which the property is perceived through a modality” for the five modalities (vision, touch, smell, gustatory, olfactory and auditory). Thus modality exclusivity ratings were obtained for each pair. Modality dominance was calculated using the cosine method which used the cosine of the angle between modality ratings for the two contexts.

2. **BLIND** (Lenci et. al., 2013) [69] contains nouns and verbs. These words were used to study concept representation in congenitally blind and sighted Italian populations. Participants generated properties for the presented words and a featural analysis was conducted on the generations. This dataset was chosen as the features could be used to calculate modality dominance. Furthermore, their data on familiarity for blind participants could provide a basis for selecting words that are more likely to be familiar for a blind population.

3. **Wordlist used by Harpainter et. al. (2018)** [9] contains a list of German abstract words taken from the German dictionary. Familiarity and Abstractness ratings were obtained for these words. This wordlist was created for studying modality representation of abstract concepts. The dataset also contained relative modality exclusivity scores.

3.1.1 Selecting Words From Wordlists

Words with i. high familiarity (equivalent to >= 4 on a five-point Likert scale), ii. words which were highly concrete or highly abstract, and iii. highly dominant in one modality were chosen. Table 3.1 details how the three selection parameters were applied to each dataset for selecting the stimuli.

After applying our selection criteria, a final list containing 346 words was obtained from the three datasets. Then a random number generator (https://docs.python.org/3/library/random.html) was used to choose 100 words, such that there were 20 Tactile, 20 Auditory, 20 Visual, 20 Internal State and Emotion and 20 Abstract words. Each modality set (Tactile, Auditory and Visual) of 20 words contains 3 property words, 2 verbs and 10 concrete words.

These words were converted to audio files using text to speech software (https://www.kukarella.com/text-to-voice-converter). Male and female in British and American accents were generated for the list of 100 words. These audio files were presented to two judges who were asked to assess the clarity of gender and accent, as well as exhaustion of rating abstraction and familiarity of 100 words, 80 words and 85 words. The judges reported female and American accent as clearer, therefore the final task only uses a female and American voices for all the audio files. For exhaustion, both judges reported high exhaustion for rating 100 words. They reported that 80 words was definitely more comfortable than 85 words. Thus, a limit of 80 words was chosen.

3.2 Norming Study

To ensure the familiarity and abstractness for words taken from an Italian, German and American database hold for our Indian population, a Norming study was conducted.

3.2.1 Participants

There were 16 participants (female = 6), aged between 21 and 26 (SD = 1.95), all of whom were part of the Cognitive-Science Lab at International Institute of Information Technology, Hyderabad. Participants were recruited through the Cognitive-Science Lab Mailing Groups. One participant was removed because their data was not stored properly on Pavlovia's database. All participation was voluntary.

3.2.2 Design

Participants rated words on Abstractness and Familiarity. To ensure there was no order effect, the words were randomized across participants. The task used auditory stimuli. Participants listened to the words and rated Familiarity and Abstractness on 5-point Likert Scales.

3.2.3 Procedure

The experiment was built on PsychoPy software and run on Pavlovia [70][71]. Participants first filled out a consent form along with demographic details of age and gender. The consent form informed the participants on Pavlovia's data storage and privacy policy. On giving consent, they were sent a link to the experiment.

Participants were instructed (full list of instructions in B to rate Familiarity on a 5-point Likert scale from Unfamiliar (rating =1) to Highly Familiar(rating =5). Familiarity was described as: if the participant knows and can explain the word comfortably.

Abstraction was also rated on a 5-point Likert scale from Highly Concrete (rating = 1) to Highly Abstract (rating = 5), where "3 = unsure." Abstraction was defined using the classical definition of abstraction [9] which is the extent to which the concept and properties of the concept can be perceived through our five senses. Refer to B.3 for the full instructions. On starting the experiment, participants were asked to fill age, nationality and gender. All the experiments running on Pavlovia are open to everybody on Pavlovia by design of the platform. Therefore, it was necessary to collect participant's Nationality to ensure that this did not become a confound. The opening instructions instructed participants on the general structure, flow, and definitions. Participants were given three trial words.

A beep was played to indicate that the participant was about to hear a word. After hearing the word, participants rated Familiarity followed by Abstractness. Participants could repeat the word as many times to ensure they heard it correctly, before rating Familiarity. After rating Abstractness a beep was played indicating that the participant was about to hear the next word. Participants rated Familiarity and Abstractness for 80 words presented randomly.

Experiment Flow: Beep $->$ Word $->$ Rate Familiarity $->$ Rate Abstraction.

3.2.4 Analysis and Results

Analysis had been primarily aimed at getting abstractness and familiarity scores for our Indian population. This would be used to then pick words from this list. On iterating through the ratings, however, we observed some interesting things that we had not expected. For example, words such as "pink" and "white," which according to the classical definition of abstractness should be highly concrete had mean rating higher than 3. Furthermore, for words with mean rating above 1, all words had a full range of ratings (from 1 to 5) as shown in table 3.2. This meant that nearly all the words had been rated both 1 and 5 by at least one participant. Based on preliminary observations, this raised the question: if the standard definition of abstractness is robust enough, then why is there so much variation?

A word of caution while interpreting these results. Since this was intended to be a norming study, the sample size is small for a full, rigorous study. While we cannot reliably say that the results are not a result of sampling bias, reading this as a pilot study, the analyses show interesting trends even within 15 participants. This at the very least warrants further investigation.

Analysis. The median instead of mean rating was taken as representative of the level of abstractness for each word. Median was chosen because the rating distributions are not normal. Words were grouped by median rating to obtain abstract and concrete words. For example, "apple" and "white," both have a median rating as 1 and are therefore grouped together. From here on rating, unless specified otherwise, refers to median rating. The resulting five groups were used to obtain abstract and concrete words. Words with rating = 1, 2 are considered concrete words. Words with rating = 4, 5 are considered abstract words. Table 3.3 describes the number of words in each level of abstractness after grouping, along with words with minimum and maximum standard deviation.

Results. The mean familiarity for all words was 4.78, SD = 0.29. We observed that there was significant difference in the mean rating between abstractness of abstract and concrete words (Wilcoxon coefficient = 660, p = 1.403e-09) consistent with previous results. Also consistent with previous studies, there was high variance (var. = 1.150) between the two kinds of concepts. The ratings showed high variation in the individual rating of abstractness (avg. var = 1.277) of words, implying a level of subjectivity in the perception of abstractness. Furthermore, the ratings had more “confusion” for abstract words than concrete words. The average variance for concrete words was 0.663, and the average variance for abstract words was 1.675. The deviation and heterogeneity of ratings are observed to increase with the level of abstraction, with only the highly concrete group of words (rating = 1) not having a lot of deviation. We also found a significant difference due to modality-specificity (Kruskal-Wallis $\chi^2(4)$ = 35.553, p = 3.576e-07). The comparison of abstractness ratings between ratings from the wordlists and an Indian population revealed a significant difference (Wilcoxon coefficient = 4911, p = 3.063e-08) suggesting a role of cultural differences in the perception of abstractness.

Tables 3.2, 3.3 describe the overall familiarity and abstractness grouped by rating.

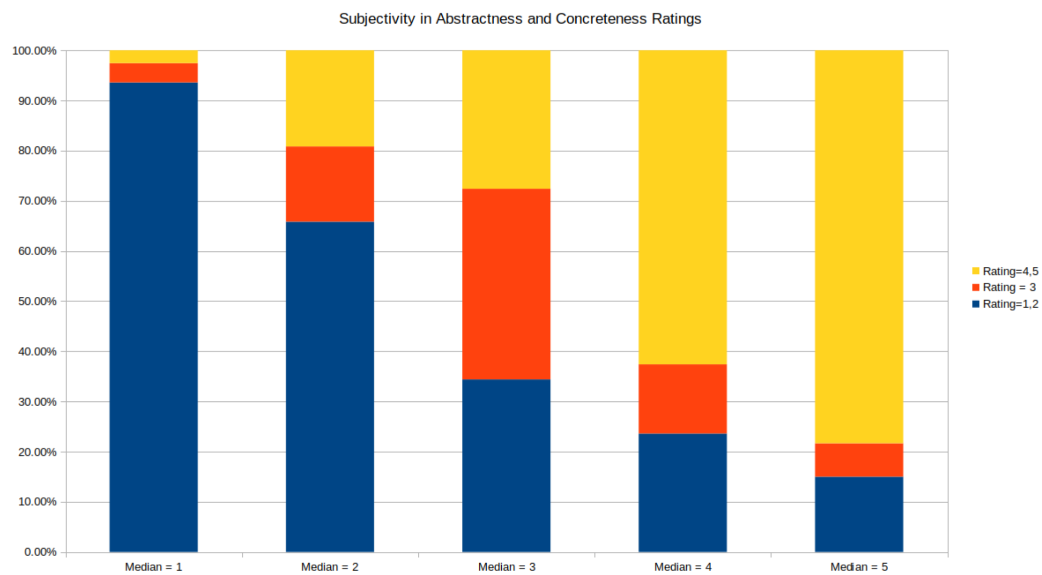

Figure 3.1 Percentages of times a word was rated abstract (rating = 4,5) and concrete (rating = 1,2). Words are grouped on median rating. Grouping by median allows us to see the pattern of variation for words with a particular overall rating.

Table 3.2 shows that all words with median rating >1 has range close to 4, implying that these words were rated on all values from 1 to 5 on the Likert Scale. Fig 3.1 shows the percentage of ratings for every level of abstractness. The ratings have been grouped into three sections: concrete (ratings 1 and 2), intermediate (rating = 3) and abstract (ratings 3 and 4). For highly abstract words (median rating =5), 20% (which is one fifth of all the ratings) are rated concrete. This means that there is considerable variance in how people have rated abstractness for highly abstract words.

Fig 3.2 shows that there is more ”confusion” on the abstract end of the levels. There is more agreement on the perception of concreteness than on the perception of abstractness. More abstract words were perceived as concrete than the vice versa.

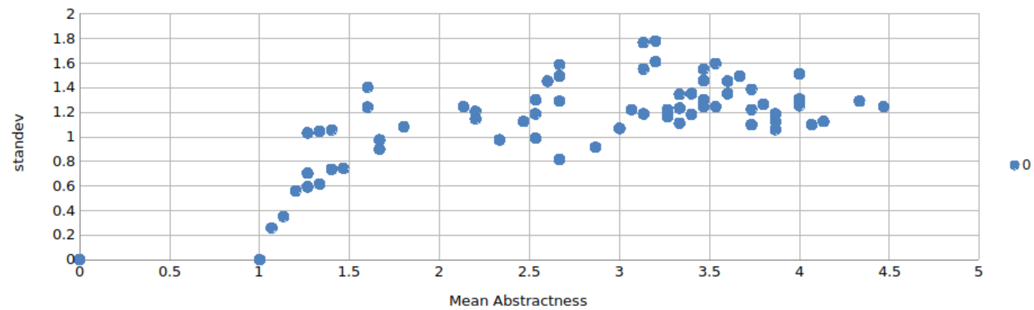

Figure 3.2 Standard Deviation plotted against mean abstractness

3.3 Discussion and Implications for Further Research

The classical definition of abstract and concrete concepts defines them in terms of perceivable features. However, given this definition to participants, there was a lot more variance than expected, with some participants rating highly abstract concepts as highly concrete. Participants also had more differences in rating more abstract concepts than concrete concepts. If the classical definition were robust enough, then there should not be this much variance.

In the last couple of years, the perception of abstractness and concreteness has gained interest in context of the two competing theories of representation: Amodal symbol systems and embodied systems. This represents a general tension in cognitive science on how these cognitive mechanisms should be understood. A tension between an analytical rationality and an ad-hoc representation based in individual experience. We clearly have a representation of "abstractness" and "concreteness," but what these mean and how they are processed and the advantages of this representation are less clear and harder to explain.

In general, abstract concepts are not grounded in particular physical, material referents. The classical definition is rooted in two concepts: "perceivable" and "features." "Perceivable" for a sighted person is different from "perceivable" for a blind person. Further, "perceivable" is different from "perceived." For a student in rural Assam, an aeroplane or blueberries are "perceivable" but they are unlikely to have ever seen these in real life. Does this personal experience effect the perception of abstractness. Previous studies have usually shown high correlations between familiarity and abstractness. To what extent is "perceivable" analytical or experiential? These are some of the questions that future studies can address.

3.4 Conclusion

These findings raise the question that if the classical definition of abstraction and concreteness is robust enough, why is there so much variation that is observed? We found high variance in the perception of concrete and abstract words. Participants rated 4 and 5 for words that should be classified as highly concrete and 1 and 2 for words that should be classified as highly abstract (Fig 3.1). The ”confusion” was observed to increased with the level of abstractness (Fig 3.2). Further, we found significant differences in ratings based on modality and culture (section 3.2.4).

Understanding the mechanisms involved in the representation of abstract and concrete concepts is paramount to understanding the mechanisms involved in knowledge representation. Furthermore, whether concepts are represented as binary or in a spectrum underlies the debate between objective Amodal Symbol System representation of concepts and the Embodied representation of concepts which emphasises subjective experience [21][7]. Our findings question the “objective” Classical definition. A possible explanation for this variation is that we do not experience all objects in equal frequencies. Some parts of the world, terrains and cultures experience certain objects more frequently, like apples in Africa vs apples in Washington, which could influence the perception of abstraction based more on experience rather than the actual perceptibility.

Parameter	Criteria	Measure Used in Dataset	Rationale
van Dantzig et. al., 2011			
Familiarity	= 1.0	binary (participants were asked to skip if the word was unfamiliar)	familiarity was calculated as the proportion of participants who skipped. If familiarity = 1, no participant skipped the word.
Abstractness	all words are considered concrete	extent to which the word is experienced through a modality	abstract concepts are defined on a lack of perceivable features. Words used in this list were chosen to measure modality specific experience. It was mathematically possible for words to have very low experience ratings on all modalities, however, there were no such words.
Modality Dominance	i) modality dominance >=0.5; ii) cosine >0.5 and unimodant ; iii)(Most Dominant Modality−2nd most Dominant Modality)>=1.0	i) Modality dominance = $\sum^{k} rating(modality_k))/5$, k=5 modalities. i) cosine is a measure of similarity between modality profiles of the word used in two different contexts. Eg. sharp knife, sharp image. Unimodant is when the word was dominant in one modality for both contexts. iii) Dominant modality is defined by the modality with the highest rating for modality specific experience	Similarity: if modality profiles vary significantly across different contexts, this could confound modality distributions in our study. E.g. sweet is modality ambiguous, it is used to describe both person and taste. Dominant Modality: van Dantzig et. al. used highest mean ratings to check modality dominance. There were words where the 1st and 2nd Dominant Modality had ratings >4 (the property is highly experienced through that modality).
Harpainter et. al., 2018			
Familiarity	>=0.5	6-Point Likert Scale. Low Familiarity (1) to High Familiarity (6); Familiarity: how often word is used, seen, heard, named or encountered	after normalisation 0.5 represented Familiarity >3 on Likert Scale.
Abstractness	modality distribution >=0.5		
Modality Dominance	Simple percent distribution. A content coding analysis was performed to get the distributions	Relative frequency of codes for the modalities was used. Harpainter et. al., had marked dominant modalities based on highest percent of code distribution.	Words dominant in Auditory, Tactile and Visual modalities were chosen.

Parameter	Criteria	Measure Used in Dataset	Rationale
BLIND (Lenci et. al., 2013)			
Familiarity	= 5 for both blind and sighted participants.	5-point Likert scale	words highly familiar to both blind and sighted participants were selected.
Abstractness	>= 0.5	judge coding	
Modality Dominance	>0.15	This dataset contains a featural analysis, not a modality dominance analysis, therefore Harpainter's Coding was used to establish modality dominance.	Harpainter's coding uses 10 variables for coding (Haptic, Visual, Gustatory, Auditory, Olfactory, Motor, Internal State and Emotion, Social Context, Concrete and Abstract Verbal Associations), making a dominance of >0.5 very rare for any of the 5 sense modalities individually, as can be seen from Harpainter's data where there are only 4 Visually dominant words and no dominance >0.5 in the other 4 sense modalities. Moreover, due to the automatic speech to text transcription, a lot of words like "often," "very," "much" etc. were added, which are neither exactly property words, nor are they modality associations, but rather parts of speech, which heavily skewed the rating towards verbal associations. Therefore a modality dominance of >0.15 was used.

Table 3.1 How parameters were applied to the three datasets for selecting words. Visual, Tactile, Auditory and Internal State and Emotion words were selected

Median	Average Abstractness	$SD_{abstractness}$	Range	Average Familiarity	$SD_{familiarity}$
1	1.26	0.58	1.29	4.92	0.31
2	2.33	1.25	3.75	4.78	0.56
3	2.89	1.20	3.78	4.50	0.40
4	3.75	1.34	3.96	4.82	0.62
5	4.23	1.29	3.75	0.69	0.25

Table 3.2 Describing the data: Average rating, average standard deviation and avergae range grouped on median rating. These statistics calculated for Abstractness and Familiarity are presented here.

Median	Word	SD	Mean	Mode
1	apple, banana, crow, hammer, pencil, pineapple	0	1	1
	white	1.4	1.6	1
2	darkness	2.67	1	1
	screeching	0.98	2.33	2
3	sore, to stroke	0.82	2.67	3
	pain	1.62	3.2	5
4	memory	1.78	3.2	5
	wonder	1.06	3.87	4
5	thought	4	5	5
	attraction	1.13	4.13	5

Table 3.3 Minimum and maximum rated words, rated on level of abstractness. Grouped on median rating.

Chapter 4

Abstraction: Investigating the Relationship Between Abstraction and Creativity

Acts of creativity, be it deciding to add dark chocolate to snicker doodle cookies or building a radio telescope capable of capturing the radio waves coming from stars in distant galaxies, necessarily come from the knowledge that exists in the mind of the creators. Because, where else would these generations come from, otherwise? Not all creative generations are chance observations, either. Traditional views of creativity saw creativity as a random, mysterious, spectacular process of coming up with ideas that no one has ever heard of. However, most often ideas build incrementally and gradually from existing ideas [72]. Dr. Martin Ryle and Dr. Antony Hewish, who helped build the radio telescope that was used to discover pulsars, both had degrees in physics, worked on engineering devices for intercepting and jamming German radio signals during World War II, and had mentors who specialised in radio astrophysics [73][74]. Their innovation was not spontaneous or random, but the result of years of training and focused work in their specialisation.

If creativity is a process of generating new knowledge, that comes out of years of practice [75], then it becomes important to study the process of acquiring and organizing knowledge to fully understand the process of creativity. Knowledge and concepts are acquired through a process of abstraction. Abstraction has come to be understood as a process of forming models, associations, features, and other semantic content through perception of similarities and patterns among our perceptuo-motor experiences [1][28][76][77]. The features, properties, structures, and exemplars formed as a result of abstraction will be referred to as "abstracted content" or "the outcomes of abstraction" or "conceptual space." While there is some theoretical recognition of the relationship between the process of abstraction and creativity, this relationship has not been well studied [1][77]. We begin by discussing the relevant literature on abstraction and creativity followed by the literature on the grounded view of cognition and creativity and then describe the importance of the present study.

4.0.1 Abstraction and Creativity Studied So Far

In literature, there has been some recognition of the role of abstraction in the creative processes. Welling (2007) [1] saw abstraction as a creative operation. Operations involved in abstraction are- pattern discovery and class creation, and when performed over existing conceptual structures can generate original solutions. He proposes abstraction as a solution to the knowledge paradox. Welling refers to Piaget's (2008) [78] distinction between abstraction from direct sensory experience, or "empirical abstraction" and abstraction over conceptual space, called "reflective abstraction" to suggest that it is the same mechanism operating on different inputs. This provides a theoretical basis for processes involved in knowledge acquisition (empirical abstraction) to be involved in creativity (reflective abstraction). The level of abstractness of problem statement formulation has been shown to facilitate creativity. Ward et al., [29][41] asked participants to imagine an animal that might live on another planet as an exemplar using specific Earth animals as reference. Participants often used features commonly associated with" Earth animals": symmetry, appendages (e. g., legs, a tail), and regular sense organs when they received no specific instructions. However, the more abstract instruction, 'think of the environment of the planet first and then think of the attributes the imagined animals require to adapt and survive 'showed significantly more unusual and novel features of imagined animals. They argued that instruction to imagine an environment on another planet and associated animals led to more novel creation because it required more abstraction to construe the problem than when participants were asked to think of the Earth animal and use that as an example to imagine an animal on another planet. Ward proposed that creative generation not only borrows from the concepts but also expands the concepts it borrows from, in a "reflective abstraction." The new imaginations add or modify existing concepts. He calls this process "conceptual expansion." Creative generations are produced from one's conceptual space, the generations once produced expand this conceptual space. This way, conceptual space, and creativity circularly feed each other.

This suggests that the organization and content of conceptual space should direct creativity. Behavioral studies on conceptual expansion show that the way we navigate our conceptual space during Divergent and Convergent Thinking is not random but structured by the existing conceptual space [29][79]. Mednick's association theory postulates that creativity is a process where two existing concepts are combined based on common contiguity. He proposed that the larger the distance between the concepts is, the higher the creativity measure will be [80]. Palmeiro [77] theorized that thinking in higher levels of abstraction or internal formulation of more abstract problems gives access to more semantically diverse categories. Studies on Divergent Thinking tasks have shown that differences in semantic organization between individuals mediate the creative process [81][79][82][77]. Certain structures are suggested to make remote contiguities more obvious: a flat, loosely associated semantic network has been shown to facilitate creativity [81][83]. The degree of conceptual expansion or the extent to which a concept is extended or modified as a result of divergent thinking is suggested to be mediated by differences in individual semantic organizations [79]. These studies show that the abstraction and shape of abstracted content are related to creativity.

Such growing evidence indicates that abstraction plays a fundamental role in shaping creativity. Despite this, there are very few accounts that talk about their relationship [29][1][28], and none which study abstraction and creativity directly. Developments in mathematics, engineering, and computer science influenced cognition to be widely modeled as amodal symbol systems where processes involved in knowledge acquisition are unrelated to higher processes like creativity [12]. Amodal model of cognition is linear and modular [14]. According to the amodal approach, the concepts are coded in a symbolic form and share no structural similarity with the perceptual states, even for concepts that are possibly closely associated with sensation, like mental imagery. Information about concepts is obtained from the perceptual systems, the properties of these concepts are abstracted into symbols and stored in static, predetermined patterns [20] which are then used for the functions of further processing. This distinction divides cognition into neat, separate parts which makes it convenient for study. However, its inherent linearity and modularity restrict the imagination from a cognition model containing circularities and the same mechanisms to be used at different stages of functioning.

4.0.2 Embodiment and Creativity

The theory of embodiment is that our actions shape thought. By extension, actions shape creativity. We act with our bodies, so the way our bodies are structured will affect our thought. This means that the body of bat or a dog, sensory deprivation or hyper functional sensory systems interact with the environment differently and therefore abstract differently. They should make different abstractions and therefore different creativity [55] [84][85].

Is is claimed that knowledge is grounded in direct sensory perception-action, internal states, emotions, and physical and social environment [6][86][6][16]. Concept representation is explained as partial traces of sensory inputs encoded by neuron activations in the respective regions of the brain, called 'partial re-enactment' [6]. Cognitive mechanisms are based on a dynamic interaction between the environment, body, and mind [12][86]. This system is interconnected, non-discrete and higher-order processes (like inference, creativity, decision making etc.) are tightly related to perceptual and internal state grounding. For example, several of the mechanisms involved in mental imagery have been found to use the same mechanisms as the visual system [24]. Increasing number of studies are relooking at cognitive processes from a framework of cognition that is shaped by the body and its interaction with the given environment.

This study, as elaborated in chapter 2, section 1.4 was originally aimed at studying abstraction and creativity in sighted and blind populations. The fact that we are primarily visually dominant should affect our concepts and for a blind person being dominant in tactile and auditory modalities should shape their abstraction and creativity. Further, the very nature of these physical structures are suggested to afford certain kinds of abstractions. For example the spatial resolution and simultaneity afforded by the visual modality is unparalleled in other modalities. Developmental studies found that young children abstract spatial properties from visual cues faster and more accurately, whereas they abstract temporal properties better for auditory stimuli [87]. This suggests that the absence of a modality should have profound effect on the structure of concept organisation.

One of the challenges for the embodied paradigm or paradigms used to study embodied cognition or grounded view of cognition has been to explain the scaling from concrete sense information to abstract concepts. Abstract concepts unlike concrete concepts do not have directly perceivable material referents that can be pointed to in real life. Similar to abstractness, creativity poses a problem for theories of embodiment or the grounded view of cognition. The ideas produced from creative thinking by definition, do not exist yet and have no material or experiential referent in the real world.Before a new piece of music is composed, it does not exist in a physical, material state that can be perceived. But how are things that have never been experienced re-enacted? The issue with abstract concepts is how are concepts like equality, fraternity, and liberty grounded in sensory information. Similarly, how does a system that operates in sensorimotor percepts create a new piece of music? While there is work examining the content of abstract concepts [6][9] there is very little work on creativity.

Most behavioural studies on embodied creativity have studied the effect of body postures on creativity, examining how more fluid postures positively influence creativity and jagged or constricted postures like tracing jagged shapes or physically sitting inside a box negatively impacted creativity [88][51]. Stanciu (2015) [52] argues that while these studies provide evidence towards the "soft" hypotheses of the theories of embodiment which state that bodily states affect abstract cognitive processing, they do no investigate the "hard" hypotheses concerning the internal representation of concepts in the sense percepts rather than abstracted symbols. In a nutshell, the semantic information associated with concepts has been studied in the context of categorization [54][53][89], the content of abstract concepts [6][9] and network models of language processing [90]. However, there is debate on the nature of this representation. The Amodal theory of concept representation claims that concepts are categorized by abstracted properties of objects and categorical taxonomic information. Alternatively, the grounded theories suggest that concepts are categorized by sensorimotor, social, and introspective abstractions. The creative processes use conceptual knowledge for coming up with creative solutions. Further, the content of creative generations has never been investigated. We use directed content analysis of concept content and of creative generations directed by amodal and embodied and more inclusive grounded view of cognition framework. Our work aims to examine the semantic content that underlies abstraction and creativity.

4.0.3 Property Generation vs Verification Task

The Property Generation Task asks participants to generate associations and features that they consider relevant and important for a set of presented concepts. This task paradigm has been frequently used to study concept representation [6], concept content [69], categorisation [54]) and semantic features ([91], [9]. Compared to a verification task which asks individuals to verify whether a property is associated with a concept or not, this task offers much more qualitative insight to individual, subjective conceptual understanding. Studies on blind participants using verification tasks have noted that a blind person is nearly as accurate as a sighted person with associating colours or other visual features with the correct objects. These studies are often used to claim that there are no significant deficits in conceptual understanding between sighted and blind populations.

This work does not want to view differences in conceptual understanding in terms of deficits, but rather as differences. Further, being able to verify need not be the same as an individual conceptual understanding, which is utilised in creative generation. One may be able to correctly associate ”yellow” as a property of ”banana,” but this need not be the property that one is *most likely to choose* to manipulate during creative generation. According to Grounded theories, individual experiences form the basis of our conceptual understanding. While creating, colour may not even be a property that a blind person uses, because these are redundant to their experience. During a pilot study conducted by us, one of the participants generated an a response, ”an aeroplane is as small as a pin.” The idea of foreshortening involved in this generation is not accessible to congenitally blind people. It is probably highly unlikely for this response to come from a congenitally blind person. This makes sense because we want to create things that are meaningful and valuable to us.

4.1 Aims and Hypotheses

This work aims to study the relationship between the process of abstraction and creativity. We are trying to explore four questions: 1) What is the role if any of sensorimotor experience on concept space and the process of abstraction. Traditional Amodal Symbol systems predict that qualities and properties are abstracted from sensory-motor experience to form the basis of our concepts. Whereas, Embodied theories predict that direct sensory-motor experience is itself the basis of our concepts. Amdoal systems predict higher entitiy property and taxonomic content whereas embodied theories predict higher sensorimotor content 2) what is the relationship between levels of abstraction and the concept space. Are higher levels of abstraction related to specific kinds of concept content? Do higher levels of abstraction predict higher amodal content? 3) is there a relationship between abstraction and creativity: can higher abstraction predict higher creativity? 4) given the inter-dependency of abstraction and creativity in literature, is there a relationship between abstraction and the strategies people employ during creative generation? Since the pandemic prevented us from collecting data from blind people, we were not able to suitably study the differences in modality specific conceptual representation and its effect on creativity. This work looks at levels of abstraction, content of concepts and their association with creativity.

This work is primarily exploratory. To explore our questions, a mixed method approach: qualitative and quantitative approach is applied to investigate underlying relationships. The categorisation scheme employed is an established scheme that is used to investigate the semantic content of concepts [91][6][9][69].

4.2 Participants

Participants with normal or corrected to normal vision were selected for this study. 50 students (male =36, female = 14, mean age = 20.48, *SD*=1.617) enrolled in a Psychology course at International Institute of Information Technology, Hyderabad, were recruited for the study. Course credits were awarded for their time and effort. To ensure the experiment was not exhausting, the stimuli were divided into two sets. To divide the sets equally, the participant pool was randomly split into two equal sets: A and B (25 participants each). The Python Random Number Generator [92] was used. The first 25 numbers serial numbers generated were assigned to set A and the rest were assigned set B. The experiment was conducted completely online on Labvanced [93]. All the participation was online and remote. Some participants faced poor or unstable connectivity while doing the experiment, especially the participants who were located in remote parts of the country. This affected the recording quality of their responses. Some participants were also unable to complete the tasks. After removing data due to technical errors, incomplete tasks and poor recording quality, 28 participants remained. This huge dropout is primarily the result of technical difficulties, lack of control over the setup a participant uses at home and instability of internet connections. Most of the data had to be removed because the recordings were very noisy. It was not possible to meaningfully comprehend and transcribe these. We could use 18 participant data for Set A and 10 participant data for Set B. To ensure that this did not confound the study a Wilcoxon Rank Sum Test was conducted. The results did not indicate significant differences between the sets except for Quantity content in Alternate Uses Task. (Results provided in Table A.2 in Appendix A.2.) Since Quantity content was very less, we did not consider this a serious confound. However, for the sake of rigour, further experimentation and coding techniques should be employed for more robust generalisation.

4.3 Tasks and Stimulus

Participants responded to four tasks:

1. A **Rating Task** similar to the rating task conducted during Norming (refer to section 3.2.3) was conducted where participants rated the auditory stimulus on Familiarity and Abstractness on 5 Point Likert Scales. This was conducted to ensure that familiarity and abstractness perceived by participants was similar to the norming.

2. A **Property Generation Task** to study abstractions [91][6][9][69]. During this task, participants were asked to respond with their "first thoughts, properties and associations that come to mind regarding the concept." They were asked to give at least 5 responses. (For full Instructions see B.3.) The Property Generation Task uses 24 words and the Alternate Uses has 18 words. These words were divided into two sets: A and B, to ensure the task did not become too exhausting. We wanted participants to give alternate uses for words that they had generated properties and

associations for, hence, all participants who did Property Generation:Set A, also did Alternate Uses:Set A. Each Property Generation set contains 12 words (24/2=12) and each Alternate Uses set contains 9 words (18/2=12). The familiarity and abstractness ratings were maintained between the two sets. All randomization was done using the Python random number generator. Please refer to the list of words in B.2.

3. An **Alternate Uses Task** to study creativity. The Alternate Uses task is a well established task used to measure Divergent Thinking [94][47]. Creativity is seen as a result of two broad processes: 1) Divergent Thinking 2) Convergent Thinking [95]. Divergent Thinking refers to an individual's ability to generate multiple, varied responses, thinking "divergently". Convergent Thinking refers to the ability to judge and converge upon appropriate solutions. Our work specifically examines the divergent process. The Alternate Uses task is a commonly used task to measure Divergent Thin [81]. Participants were asked to generate "as many unusual, weird and uncommon uses as they could think of." They had to give at least 3 responses. (Full Instructions in B.3.2).

The tasks were auditory tasks. Stimuli were audio words and participants gave responses verbally. This design was specifically chosen for blind participation (refer to 1.4). Participants were instructed to listen to the presented words carefully and register their responses on a microphone or their computer recording hardware. This experiment was conducted completely online. To make the task less exhausting, two sets were used. The descriptions of the two tasks are given below.

4.4 Procedure

The two sets of participants were sent online consent forms containing a link to the respective task set. The experiment was designed on Labvanced [93]. During both tasks, participants were asked to listen to the presented words carefully and register their responses on their computer recording hardware or a separate microphone. This experiment was conducted completely online.

On opening the link, participants were directed to the instructions page which outlined the structure and conducted a volume test to ensure that the volume was set to a comfortable level. Since we wanted the participants to do the Creativity Task after they had generated associations and properties, all participants responded to the Property Generation Task followed by the Creativity Task. A fixed order was used because we wanted to see whether having generated associations for a word before generating alternate uses made a difference to creativity. In the Alterneate Uses Task, a mix of both old and new words were randomly presented. To reduce fatigue from responding to multiple words, the experiment was designed such that a second link directing participants to the Creativity Task was scheduled to open only 10 minutes after the first task was completed.

During the Property Generation Task, participants heard a beep indicating that they were about hear the word. They rated the word on Familiarity and Abstractness (refer to the full instructions in B.3) on five-point Likert scales. This process was conducted exactly as as the norming (refer to 3.2.3). These ratings were taken to ensure that the words were familiar and the perception of abstractness matched our norming. Followed, by rating, participants recorded their responses. A blank slide informed the participant that their response had been recorded correctly. This flow was repeated for all words. Words were presented randomly across participants, from the respective Set Lists.

The Alternate Uses Task followed the same experimental flow as Property Generation. Participants responded with weird, alternate uses for the object words presented. The full instructions are provided in B.3.2. Words were randomised across participants for their respective task sets. There were two cases, where the order was jumbled due to technical issues on the hosting site. These participants' data was removed.

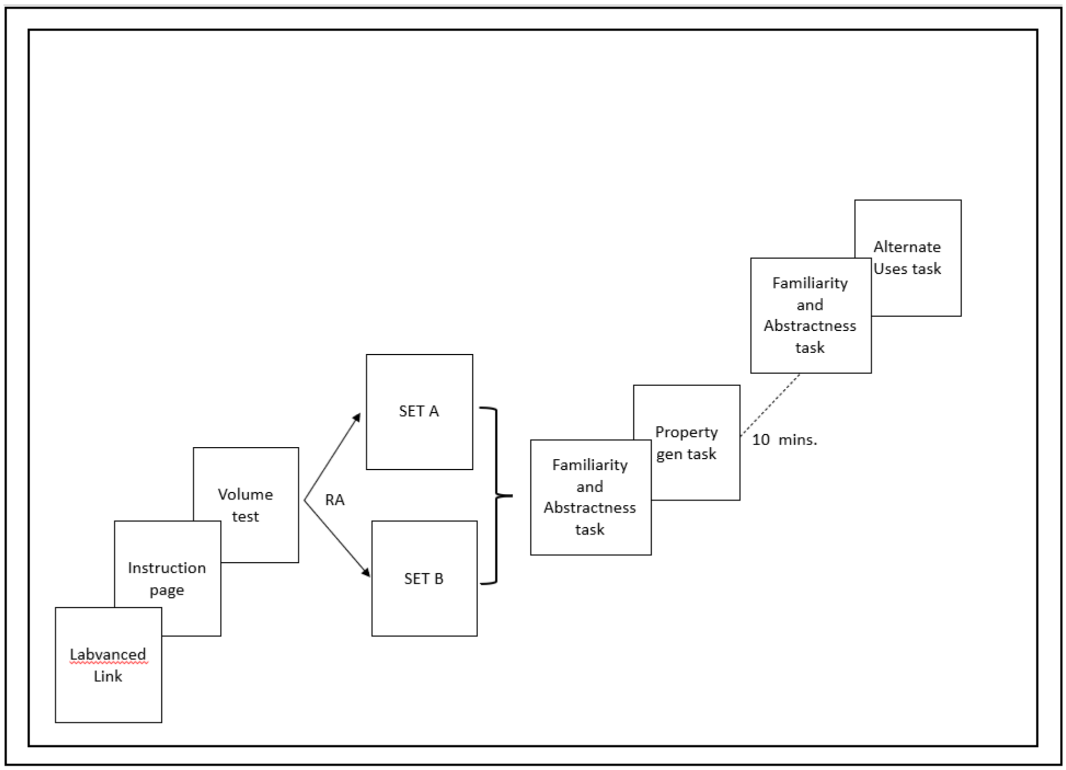

Figure 4.1 Schematic representation of the flow of the experiment. (RA stands for random allocation, here the sets were randomly allocated to the participants). There was a 10-minute break after the Property Generation task.

4.5 Analysis

The responses generated from both tasks were manually transcribed and scored. Due to background noise or bad network connectivity, some recordings had very low quality and could not be meaningfully transcribed. Words which were unfamiliar, misheard by the participants, and those with poor recording quality were marked invalid. Each valid response was scored by three independent judges (unless men-

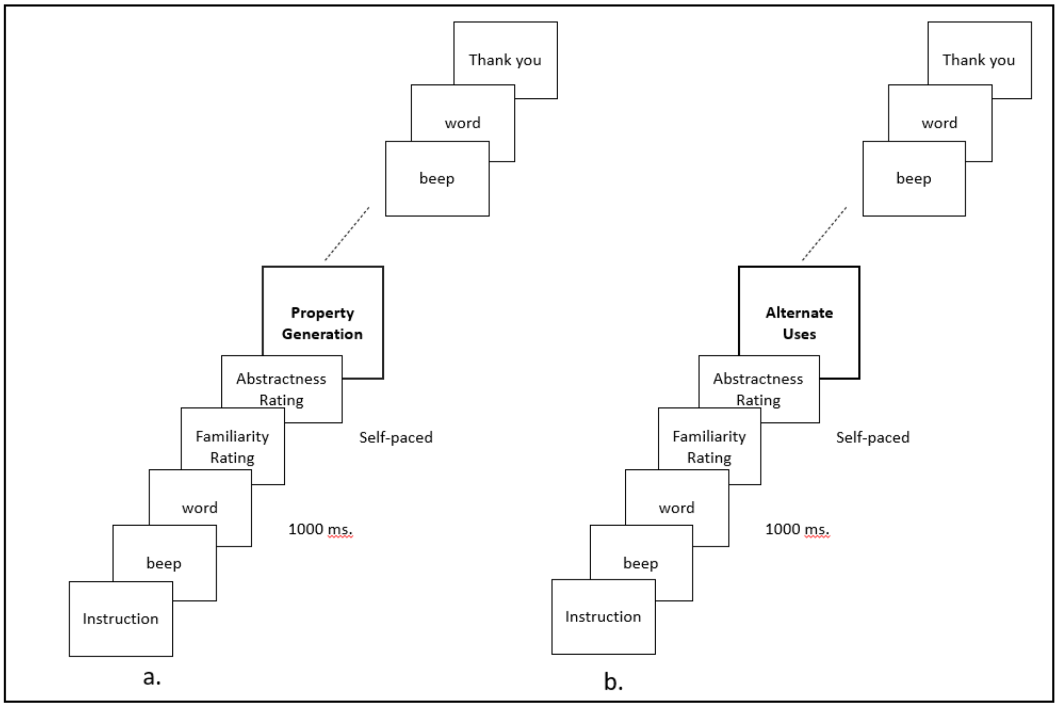

Figure 4.2 Schematic representation of the flow of each task. a. Property Generation Task (PGen), and b. Alternate Uses Task (AUT).

tioned otherwise) on all the scoring parameters. The analysis was conducted on four major parameters: i) Content Coding of responses ii) level of abstractness iii) creativity (Guilford) iv) divergent thinking strategies. The scores were calculated and ordered individual-wise.

Analysis was conducted on four fronts:

1. Content Coding: analysis of content based on frequencies of code distributions for both Alternate Uses and Property Generation
2. Creative Ability and Abstraction: how creative ability varies with level of abstraction.
3. Associations between Creativity and Abstraction: correlational analysis investigating associations between Creativity and Abstraction.
4. Divergent Thinking Abilities: examining associations between level of abstraction and content of Alternate Uses and Property Generation.

4.5.1 Content Coding

Content coding is a qualitative analysis technique used for content analysis [96]. A directed content coding approach is used. While traditional content analysis uses the given text to drive coding, a directed approach uses selected theories or frameworks to direct coding. Grounded and Amodal theories formed the basis for directing our coding. The codes we use are borrowed and modified from Barsalou et. al., 2005 [6], Lenci et. al., 2013[69] and Harpainter et. al., 2018[9]. Barsalou et. al. and Harpainter et. al., were studying concepts under an embodied paradigm, and Lenci et. al. was studying concept content in blind people.

To study concept content in both the concept space and creative generation, Property Generation and Alternate Uses were coded using this scheme. We used a hierarchical coding system with 5 major codes and multiple subcodes for each category.

The Six major codes used to categorise the data are given below:

1. **Situation (S):** contexts where the concept is encountered. Eg: apples: apples are a winter fruit, apple: “apple of my eye.”

2. **Taxonomy (T)**: relating to taxonomic structure Eg: synonyms, antonyms; apple: apple is a fruit; apple: banana (at same level of assumed taxonomic structure)

3. **Entity Property (E)**: properties of concept. Eg: apple: apples are nutritious; apple: apple is crunchy.

4. **Introspection (I)**: internal states, subjective evaluative judgements and affective states. Eg: apple: Apple is my favourite fruit; apple: I feel sad when I think of apples.

5. **Quantity (Q)**: relating to quantities describing the concept. Eg: apple: I bought six apple last evening from the farmer’s market; dog: dog has four legs

The subcategories are as follows:

(Taxonomic (T) isa: Hypernym or response is a superordinate category of a concept Eg: cat– animal **coo:** Coordinates or concepts at the same level in the taxonomic hierarchy. Eg: cat– dog **syn:** Synonyms. Eg: creativity– innovation. **ant:** Antonym Eg:hate– love. **exa:** Example of the concept. Eg: horse– roans. **ins:** Instance. Eg: mountain– Alps.

Entity Property (E) mer: Meronym or parts of the concept. Eg:car– wheel. **hol:** Holonym or larger things the concept constitutes. Eg: seagull– flock. **mad:** Made of. Eg: comb– plastic. **ppe:** Perceptual property or all features corresponding to qualities that can be directly perceived, such as magnitude, shape, taste, texture, smell, sound, and colour. Eg: cat– big. **pnp:** Non directly perceptual property i.e the properties that cannot be directly perceived through the senses. Eg: cat– sociable

Situation (S) eco: Entity of concrete type or concrete objects that participate in the same events and situations along with the stimulus concept. Eg: hammer– nail. **eab:** Entity of abstract type or abstract categories associated with the stimulus. Eg: dog– friendship. **eve:** Events. Eg:memory: storing. **act:** Action. Eg: hammer- throw. (this code distinguishes between physical and non physical action; only physical actions are considered.) **sc:** Social Constellation, if a response involves the interation of two or more people. **spa:** Space or typical spaces where one would encounter the stimulus concept. Eg: zebra– savanna. **tim:** Time. Eg: tomato– summer. man: Manner. Eg: stroke– gently.

Introspection (I) eva: Subjective evaluation, affective and internal states. Eg: lion– fear.

Quantity (Q) qua: Quantity. Eg: car– four wheels.

We noticed that some responses had multiple codes applicable to them or were ambiguous. Eg: "I fondly remember using pencils in my childhood until we started using pens," has both an introspective component from "fondness" and a situation component from "childhood." Therefore, this study employs a coding scheme where multiple codes are assigned to each response, if they are applicable. All code frequencies are summed and normalised over the number of valid words per participant. A concatenation of all codes is taken as the final coding for each response.

Scores were calculated participant-wise and modality-wise. Participant-wise scores were calculated by normalising each scoring parameter over the number of valid words (i.e. the words remaining after removal of unfamiliar, misheard and poorly recorded words).

The Content coding uses a weighted relative frequency score for each code category, per participant. A normalised frequency score of a code category was obtained by the number of times the code was assigned to the responses given by each participant, divided by the number of valid words. This was calculated for all three judges independently. The final score is a mean of the three code frequencies for each code category.

Modality-wise distributions are a summation of each category code within each set of modality dominant words (Auditory, Visual and Tactile).

4.5.1.1 Results for Concept Coding

Property Generation had a total of 2090 responses (N (participants)=28, 24 words). The average number of responses generated by a participant for each concept was 4.68 (*SD* = 1.67). For the Alternate Uses task, a total of 996 responses were generated (N=28 participants, 18 words). The mean responses per participant, per word was 3.03 (*SD* = 1.03). Both abstractness and familiarity was very similar to the norming. Average familiarity was high (4.489, *SD* = 1.05). For AU, all words matched the median abstractness rating found during norming. For Property Generation, all words except 5 (white, window, danger, to stroke and to spot) matched the norming ratings. White (rating = 2, norming rating = 1), to stroke (rating = 4, norming rating = 3) and to spot (rating = 4, norming rating = 3) were rated one point more abstract than norming. Danger (rating = 4.5, norming rating = 4) was rated 0.5 points more than norming. Window (rating = 1, norming rating = 2) was rated one point more concrete than the norming. Since the ratings are not very different, we consider that the words were perceived at the level of abstractness as chosen.

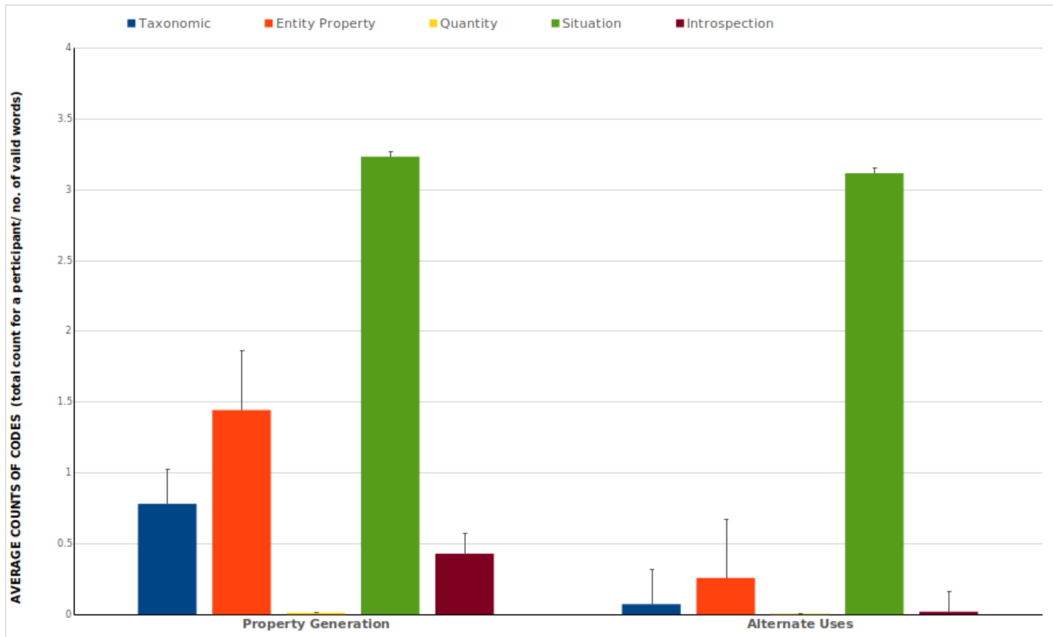

Figure 4.3 Mean code distribution for a response for Property Generation and Alternate Uses. Mean is calculated per participant normalised over number of their valid words.

Fig. 4.3 shows that situation is the most highly generated category of response for both the Property Generation Task (3.23, *SD* = 1.20) and the Alternate Uses task (3.11, *SD* = 1.06). Followed by Entity Properties (Property Generation: 1.45, *SD* = 0.86; Alternate Uses: 0.26, *SD* = 0.35) and Taxonomic type (Property Generation: 0.78, *SD* = 0.42; Alternate Uses: 0.07, *SD* = 0.12) of associations. This is in line with Embodied theory of conceptual knowledge, which emphasises individual experience and context as the basis for concept content.

Fig. 4.3 also shows that the count of distribution for Taxonomic (Property Generation: 0.78, *SD* = 0.42; Alternate Uses: 0.07, *SD* = 0.12) and Situation (Property Generation:3.23, *SD* = 1.20; Alternate Uses: 3.11, *SD* = 1.06) properties for Alternate Uses and Property Generation is the same. The frequency of the Introspection code (Alternate Uses = 0.02, *SD* = 0.05; Property Generation = 0.43, *SD* = 0.35) and Entity Property differ between the Tasks. This means that, there were very few responses that contained parts like ”annoyed” or ”happy,” in the alternate uses generations, whereas there were higher number of associations containing internal states for Property Generation.

There was significant difference between the distribution frequencies of codes in both Property Generation [H(4) = 122.75, $p < 0.01$)] and Alternate Uses [H(4) = 103.98, $p < 0.01$]. Since the distributions of alternate uses violated the normality assumption, a nonparametric test was used (Kruskal-Wallis). Post hoc tests comparing differences between individual frequency distributions showed significant differences for all sets of code distributions in Property Generation ($p_{holm} < 0.05$, for all comparisons, Holm corrected for familywise error). For Alternate Uses, some pairs of distributions were not significantly different: introspection – quantity (p_{holm} = 0.33), instrospection – taxonomy (p_{holm} = 0.15) and taxonomy – quantity (p_{holm} = 0.09). To check whether there were any differences in the frequency counts of the codes between the two tasks, a non-parametric repeated measures analysis of variance was used (Freidman). There was significant difference between the distributions of the two tasks calculated by the Freidman's test (χ^2 = 18.51, $p < 0.05$).

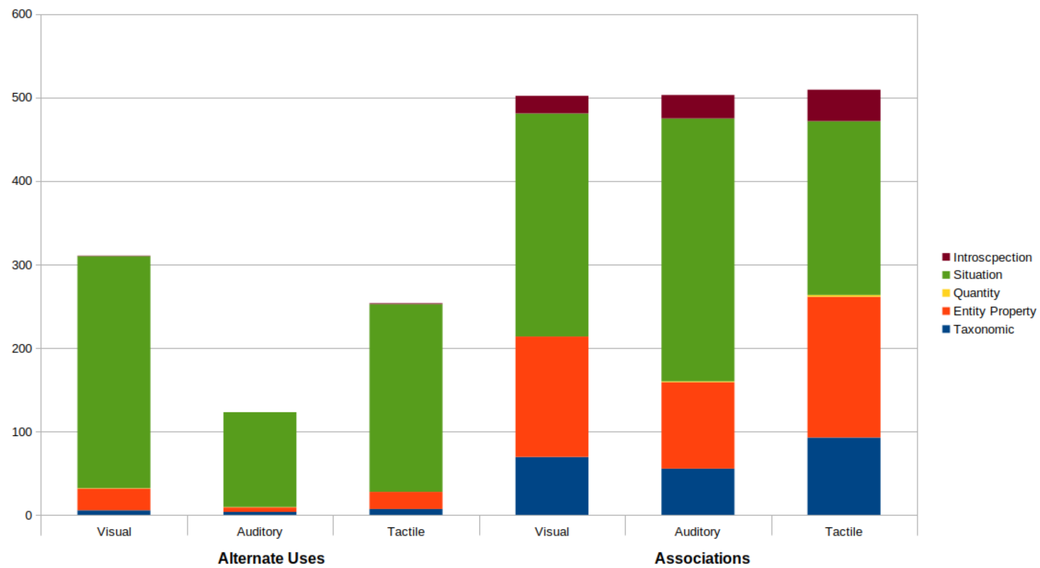

Figure 4.4 Count of codes for each modality in Property Generation (Associations) and Alternate Uses. The counts are calculated by summing each code category within the set of modality dominant words for each modality.

4.5.1.2 Modality-wise Distribution Counts

The total number of codes generated per modality, i.e. the count of each code for auditory, visual and tactlie dominant words across all participants was calculated and plotted in 4.4.

The modality-wise distribution in Fig 4.4 shows that responses generated for the Auditory modality dominant words had fewer Taxonomic (AU = 103.67, P.Gen = 5.50) and Entity Property (AU = 3.5, P.Gen = 55.33) categories than the other modalities. More Situation associations (P.Gen = 315.0) were also generated for Auditory dominant words.

Tactile dominant words had the highest frequency of Introspection type responses (AU = 1.0, P.Gen = 37.67) for both tasks.

Quantity codes are negligible (AU = 1.0, P.Gen = 3.0) for all modalities in both tasks.

Figure 4.5 shows a breakdown of the sub-codes for the Situation code category, to see which particular codes occurred more frequently.

Concrete associations were the highest kind of Situation sub-category generated for both tasks (AU = 1.92, P.Gen = 1.42). The action sub-code has high frequency for Alternate Uses (AU = 1.61). Action

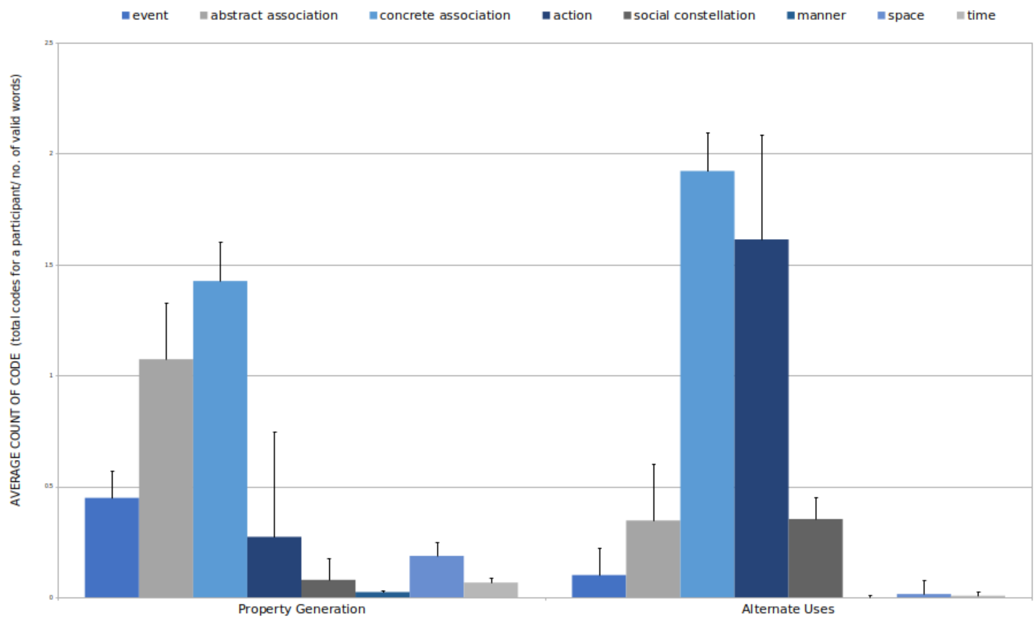

Figure 4.5 Mean distribution of sub-codes within the Situation code category. Figure shows the count for both Property Generation and Alternate Uses. Mean is calculated per participant normalised over number of their valid words. (Note: Abstract words have been excluded here as they are not considered to be particularly dominantly perceived through any one modality.)

has a relatively low frequency for Property Generation, contrary to what the embodied theories predict. They primarily emphasise motor action as basis of conceptual knowledge. Fig. 4.5 also shows high frequencies of abstract associations generated for the words presented (1.07). The frequency for Alternate Uses, is relatively much lower (0.34). The third most frequently generated Situation- Type Alternate Use was social constellation (0.35), which had a relatively low distribution for Property Generation (0.08).

4.5.2 Individual Creativity and Level of Abstractness

Creativity: Guilford's scoring method was used to assess creativity. Guilford's method uses 4 factors for assessment:

1. Fluency: It measures the ability to generate a large number of response per unit time (guilford). This score was obtained by a count of the total number of responses generated by each participant. Since this is an objective measure, there was no judge rating used.

2. Flexibility: This measures the ability of generating different kinds of responses. This is intended to measure of how easily one can ”shift sets” [94]. This was scored was obtained by giving a flexibility count to each word and taking a mean per participant. For e.g., Knife: ”cutting vegetables, using knife to cut bottles open, using knife as mirror” will get a flexibility count of 2. Both the first and second responses use knife as a cutting tool, therefore are awarded only 1 point.

Table 4.1 Bayesian Kendall's Tau Correlations between Category codes for Alternate Uses and Property Generation.

Alternate Uses		Proroperty Generation				
Variable		Taxonomic	Entity Property	Quantity	Situation	Introspection
1. Taxonomic	Kendall's tau	0.003	0.078	0.148	0.153	0.174
	BF_{10}	0.243	0.287	0.437	0.456	0.548
	Upper 95% CI	0.245	0.313	0.375	0.380	0.398
	Lower 95% CI	-0.239	-0.172	-0.109	-0.104	-0.085
2. Entity Property	Kendall's tau	0.496***	0.340	0.303	0.179	0.238
	BF_{10}	172.371	5.330	2.832	0.573	1.104
	Upper 95% CI	0.680	0.546	0.513	0.403	0.455
	Lower 95% CI	0.205	0.065	0.032	-0.081	-0.028
3. Quantity	Kendall's tau	-0.050	-0.014	0.249	0.100	-0.158
	BF_{10}	0.260	0.245	1.280	0.318	0.475
	Upper 95% CI	0.197	0.229	0.465	0.332	0.099
	Lower 95% CI	-0.288	-0.255	-0.017	-0.152	-0.385
4. Situation	Kendall's tau	0.505***	0.434**	0.297	0.396*	0.270
	BF_{10}	217.000	37.301	2.568	15.988	1.722
	Upper 95% CI	0.688	0.628	0.508	0.594	0.484
	Lower 95% CI	0.212	0.149	0.026	0.115	0.002
5. Introspection	Kendall's tau	0.421	0.466**	0.185	0.299	0.357
	BF_{10}	27.612*	79.836	0.607	2.661	7.356
	Upper 95% CI	0.616	0.655	0.408	0.510	0.561
	Lower 95% CI	0.138	0.178	-0.076	0.028	0.080

The third response uses knife as mirror which is different from cutting, therefore another point is awarded.

3. Originality: This is a measure of how new or unheard of a response is. This was scored by three judges on a 5-point Likert scale, from unoriginal (1) to highly original (5). The interrater reliability was good (ICC(C,3) = 0.757, p = 1.49e-120, CI: 0.726 $<$ ICC $<$ 0.786).)

4. Elaboration: This is a measure of how detailed the response is. For e.g., window: ”to see the scenery outside” will score lesser than window:”seeing the scenery outside the window of trees and a garden or a beach view can be peaceful.”

Abstractness of each response was scored by three judges based on the classical definition of abstractness (also, refer to 3). The classical definition defines abstractness as a lack of perceivable features. Judges scored each response on a 5-point Likert Scale from highly concrete (1) to highly abstract (5) (refer to B.3.3. There was high interrater agreement for abstractness scores. This was calculated by Interclass Correlation Coefficient which is used for evaluating agreement for ordinal scoring (ICC(C,3) = 0.831, F(233,466) = 5.91 , p = 1.27e-59, CI: 0.789 $<$ ICC $<$ 0.865).

An individual score for each participant was calculated by summing the abstractness scores over all their responses and dividing by the number of valid words.

A Bayesian correlation was conducted between individual creativity and individual abstractness. Since the variables were non-parametric, Kendall’s Tau was used.

4.5.2.1 Results for Individual Creativity and Abstractness

Variable		Fluency	Flexibility	Originality	Elaboration
Abstractness	Kendall’s tau	0.541***	0.119	0.444***	0.296
	BF_{10}	596.200	0.355	47.519	2.548

Table 4.2 Bayesian Kendall’s Tau Correlations between abstraction and individual creativity scores. For rejecting the null hypothesis, *$BF_{10} > 3$, **$BF_{10} > 10$, ***$BF_{10} > 30$. For accepting the null hypothesis, *$BF_{10} < 0.33$, **$BF_{10} < 0.10$, ***$BF_{10} < 0.033$.

Table 4.2 shows that abstractness correlates highly and significantly with Fluency (tau = 0.541, BF_{10} = 596.2) and Originality (tau = 0.444, BF_{10} = 47.5). Whereas, the correlation with elaboration and Flexibility were not significant. In fact Flexibility has some evidence (BF_{10} = 0.36) for no relationship with abstractness. This is in line with previous research suggesting that high abstraction ability may lead to a larger concept space, resulting in larger quantities (Fluency) of responses [41].

4.5.3 Correlational Analysis

Bayesian analysis was carried out between all the scoring variables to investigate relationships that may emerge between abstractions and creative generation. Bayesian analyses gives a likelihood of rejecting a null hypothesis. This is unlike the binary accept or reject of p-values that is based on a single acceptance number. This allows a more holistic understanding of the results. This is particularly useful for considering the robustness of results from a low sample size like ours.

4.5.3.1 Abstraction and Creativity Content Analysis

Table 4.3 shows that level of abstractness of associations correlated with Situation (tau = 0.48, BF_{10} = 101.4) and Introspective (tau = 0.51, BF_{10} = 254.9) alternate uses. A possible explanation for the correlation of Introspective generations is Piaget's "reflexive abstraction" which is abstracting internally over existing concept space. People who tend to engage in reflexive thinking more often are probably more likely to generate more outcomes related to their own internal states and evaluations. The association of Situation is more counter-intuitive, while abstractness is about going further away from material referents, situation refers to specific contexts where these concepts are encountered. This is another indication of how context specificity and abstractness need not be antagonistic to each other.

Variable			Taxonomic	Entity Property	Quantity	Situation	Introspection
Abstractness	Kendall's tau	–	0.179	0.407**	0.014*	0.475***	0.511***
	BF_{10}	–	0.575	20.171	0.245	101.397	254.891
	Upper 95% CI	–	0.403	0.604	0.255	0.663	0.693
	Lower 95% CI	–	-0.080	0.125	-0.230	0.186	0.218

Table 4.3 Bayesian Kendall's Tau Correlations between codes of Alternate Uses and Abstractness. For rejecting the null hypothesis, *$BF_{10} > 3$, **$BF_{10} > 10$, ***$BF_{10} > 30$. For accepting the null hypothesis, *$BF_{10} < 0.33$, **$BF_{10} < 0.10$, ***$BF_{10} < 0.033$.

4.5.3.2 Association Content Analysis and Guilford's Scoring

Bayesian correlation between Property Generation codes and individual creativity scores revealed a significant, high correlation between Originality and Situation (tau = 0.56, BF_{10} = 1059.4).

4.5.3.3 Property Generation and Alternate Uses Code Categories

(Table 4.5) Taxonomic associations correlate with Entity Property Based Alternate Uses (tau = 0.50, BF_{10} = 172.4), Situation or context specific based alternate uses (tau = 0.50, BF_{10} = 217.0) and Introspective alternate uses (tau = 0.42, BF_{10} = 27.6).

4.5.4 Divergent Thinking Strategies

This coding scheme was developed to score alternate uses tasks based on which strategies might be employed by participants while coming up with alternate uses [97]. Matheson et. al. used 7 binary pairs

Variable		Fluency	Flexibility	Originality	Elaboration
Taxonomic	Kendall's tau	0.411**	0.065*	0.404**	0.218
	BF_{10}	22.382	0.273	19.167	0.869
	Upper 95% CI	0.608	0.301	0.602	0.438
	Lower 95% CI	0.129	-0.184	0.123	-0.045
Entitiy Property	Kendall's tau	0.289	0.000*	0.239	0.101*
	BF_{10}	2.267	0.243	1.118	0.319
	Upper 95% CI	0.501	0.242	0.456	0.333
	Lower 95% CI	0.019	-0.242	-0.027	-0.151
Quantitiy	Kendall's tau	0.056*	-0.137	0.102*	0.046*
	BF_{10}	0.265	0.402	0.321	0.258
	Upper 95% CI	0.293	0.118	0.333	0.284
	Lower 95% CI	-0.191	-0.366	-0.151	-0.201
Situation	Kendall's tau	0.450***	0.270	0.561***	0.296
	BF_{10}	53.714	1.720	1059.435	2.548
	Upper 95% CI	0.641	0.484	0.734	0.507
	Lower 95% CI	0.163	0.002	0.262	0.026
Introsepection	Kendall's tau	0.358*	0.082	0.277	0.405**
	BF_{10}	7.519	0.291	1.905	19.621
	Upper 95% CI	0.562	0.316	0.490	0.603
	Lower 95% CI	0.081	-0.169	0.009	0.124

Table 4.4 Bayesian Kendall's Tau Correlations between individual creativity scores and Association codes. For rejecting the null hypothesis, *$BF_{10} > 3$, **$BF_{10} > 10$, ***$BF_{10} > 30$. For accepting the null hypothesis, *$BF_{10} < 0.33$, **$BF_{10} < 0.10$, ***$BF_{10} < 0.033$.

for categorisation. In our responses we found that scoring did not always apply as a binary one or the other, therefore, all responses are scored on 14 strategies. The scoring was 1 if strategy was used and 0 if it was not. All responses were scored on all 14 strategies. The scores were summed and normalised for each word.

The strategies are:

1. **Analogy:** The use is based on an analogy Eg. pencil: use pencil as a stick.
2. **Action:**The use is based on action simulation. Eg. pencil: pencil is used to poke someone.
3. **Whole**Whole object is used. Eg. chair: chair is used to break a window.
4. **Part:** A part of the object is used. Eg. chair: the leg of a chair is used to dig a hole.
5. **Same** Action typically associated with the object is applied. Eg. knife: knife is used to cut a bottle.
6. **Different:** A completely different action than that associated with the object is used. Eg. pencil: food processor.

Alternate Uses		Property Generation				
		Taxonomic	Entity Property	Quantity	Situation	Introspection
Taxonomic	Kendall's tau	0.003*	0.078*	0.148	0.153	0.174
	BF_{10}	0.243	0.287	0.437	0.456	0.548
	Upper 95% CI	0.245	0.313	0.375	0.380	0.398
	Lower 95% CI	-0.239	-0.172	-0.109	-0.104	-0.085
Entity Property	Kendall's tau	0.496***	0.340	0.303	0.179	0.238
	BF_{10}	172.371	5.330	2.832	0.573	1.104
	Upper 95% CI	0.680	0.546	0.513	0.403	0.455
	Lower 95% CI	0.205	0.065	0.032	-0.081	-0.028
Quantity	Kendall's tau	-0.050*	-0.014*	0.249	0.100*	-0.158
	BF_{10}	0.260	0.245	1.280	0.318	0.475
	Upper 95% CI	0.197	0.229	0.465	0.332	0.099
	Lower 95% CI	-0.288	-0.255	-0.017	-0.152	-0.385
Situation	Kendall's tau	0.505***	0.434***	0.297	0.396**	0.270
	BF_{10}	217.000	37.301	2.568	15.988	1.722
	Upper 95% CI	0.688	0.628	0.508	0.594	0.484
	Lower 95% CI	0.212	0.149	0.026	0.115	0.002
Inrospection	Kendall's tau	0.421**	0.466***	0.185	0.299	0.357*
	BF_{10}	27.612	79.836	0.607	2.661	7.356
	Upper 95% CI	0.616	0.655	0.408	0.510	0.561
	Lower 95% CI	0.138	0.178	-0.076	0.028	0.080

Table 4.5 Bayesian Kendall's Tau Correlations between Property Generation codes and Alternate Uses codes. For rejecting the null hypothesis, *$BF_{10} > 3$, **$BF_{10} > 10$, ***$BF_{10} > 30$. For accepting the null hypothesis, *$BF_{10} < 0.33$, **$BF_{10} < 0.10$, ***$BF_{10} < 0.033$.

7. **Concrete:** The use is concrete and has perceivable, physical referent. Eg. window: window is used as prop for carrying around to act like a madman in acting class.

8. **Abstract:** The use is abstract in nature. Eg. Window: represents opportunities.

9. **Familiar:** A common use of object. Eg. pencil: used to tie hair in a bun.

10. **Novel:** Completely novel use of the object. Eg. brick: powder the brick and use the powder to grow new plants.

11. **Towards the body:** Action is towards the body. Eg. pencil: pencil for scratching your ear.

12. **Away from the body:** Action is away from the body. Eg. pencil: throw pencil at someone who is annoying you.

13. **Egocentric:** Action is from a first person perspective. Eg. cherry: using cherry to stain my brother's shirt and blaming him for it to the parents.

14. **Allocentric:** Action is from a world view. Eg. cherry: cherries are used in confectioneries.

Creativity Strategies (Matheson's Scoring method): This was calculated similar to the code distributions. Individual scores are a sum of individual response strategy scores divided by the number of valid words. Each strategy was scored separately. 14 strategy scores were generated for each individual. Table4.6 presents the results for divergent thinking strategies correlated with abstractness.

DT Strategies	Abstractness	
	Kendall's Tau	BF_{10}
Analogy	-0.070*	0.278
Action	0.146	0.431
Part	-0.158	0.473
Whole	0.090*	0.302
Same Action	-0.072*	0.279
Different Action	-0.061*	0.269
Concrete	-0.051*	0.261
Abstract	0.229	0.985
Familiar	-0.310*	3.156
Novel	-0.115	0.347
Towards	0.032*	0.250
Away	0.004*	0.243
Egocentric	-0.073*	0.281
Allocentric	0.004*	0.243

Table 4.6 Bayesian Kendall's Tau Correlations between Abstractness and Divergent Thinking strategies.For rejecting the null hypothesis, *$BF_{10} > 3$, **$BF_{10} > 10$, ***$BF_{10} > 30$. For accepting the null hypothesis, *$BF_{10} < 0.33$, **$BF_{10} < 0.10$, ***$BF_{10} < 0.033$.

		Property Generation				
Variable		Taxonomy	Entity Property	Quantity	Situation	Introspection
1. Analogy	Kendall's tau	0.008	-0.093	-0.264	0.321	0.019
	BF_{10}	0.244	0.307	1.578	3.854	0.246
	Upper 95% CI	0.249	0.158	0.003	0.529	0.259
	Lower 95% CI	-0.235	-0.326	-0.479	0.048	-0.225
2. Action	Kendall's tau	0.432*	0.481***	0.343	0.180	0.310
	BF_{10}	35.550	117.945	5.625	0.581	3.190
	Upper 95% CI	0.626	0.668	0.548	0.404	0.519
	Lower 95% CI	0.148	0.192	0.067	-0.079	0.038
3. Whole	Kendall's tau	0.459**	0.404*	0.259	0.419*	0.235
	BF_{10}	66.871	19.165	1.472	26.539	1.071
	Upper 95% CI	0.649	0.602	0.474	0.615	0.453
	Lower 95% CI	0.171	0.123	-0.008	0.136	-0.030

4. Part	Kendall's tau	0.311	0.213	0.127	0.223	0.280
	BF_{10}	3.248	0.822	0.374	0.926	1.968
	Upper 95% CI	0.520	0.433	0.356	0.443	0.492
	Lower 95% CI	0.039	-0.050	-0.128	-0.041	0.011
5. Diff Action	Kendall's tau	0.333	0.247	0.028	0.532***	0.280
	BF_{10}	4.712	1.245	0.248	465.775	1.994
	Upper 95% CI	0.540	0.464	0.267	0.711	0.493
	Lower 95% CI	0.059	-0.019	-0.217	0.237	0.011
6. Same	Kendall's tau	0.378*	0.435**	0.270	0.157	0.287
	BF_{10}	10.977	38.318	1.704	0.471	2.213
	Upper 95% CI	0.579	0.629	0.484	0.383	0.499
	Lower 95% CI	0.099	0.150	0.002	-0.100	0.017
7. Abstract	Kendall's tau	0.085	0.072	0.162	0.151	0.254
	BF_{10}	0.296	0.279	0.493	0.449	1.374
	Upper 95% CI	0.319	0.307	0.388	0.378	0.470
	Lower 95% CI	-0.165	-0.177	-0.096	-0.106	-0.013
8. Concrete	Kendall's tau	0.547***	0.500***	0.269	0.371	0.219
	BF_{10}	699.253	191.580	1.677	9.707	0.881
	Upper 95% CI	0.722	0.684	0.483	0.573	0.439
	Lower 95% CI	0.250	0.208	5.003e-4	0.093	-0.044
9. Familiar	Kendall's tau	0.430**	0.264	0.093	0.475***	0.286
	BF_{10}	33.882	1.563	0.306	101.397	2.187
	Upper 95% CI	0.624	0.478	0.325	0.663	0.499
	Lower 95% CI	0.146	-0.004	-0.159	0.186	0.017
10. Novel	Kendall's tau	0.232	0.338	0.223	0.247	0.195
	BF_{10}	1.031	5.184	0.916	1.245	0.676
	Upper 95% CI	0.450	0.544	0.442	0.464	0.418
11. Away	Kendall's tau	0.269	0.354	0.112	0.503***	0.270
	BF_{10}	1.682	6.925	0.340	205.864	1.700
	Upper 95% CI	0.483	0.558	0.343	0.686	0.484
	Lower 95% CI	5.003e-4	0.078	-0.141	0.211	0.002
12. Towards	Kendall's tau	0.551***	0.437**	0.324	0.161	0.255
	BF_{10}	801.947	39.626	4.024	0.488	1.382
	Upper 95% CI	0.726	0.630	0.532	0.387	0.470
	Lower 95% CI	0.254	0.152	0.051	-0.097	-0.012
13. Egocentric	Kendall's tau	0.455**	0.380*	0.407*	0.257	0.334
	BF_{10}	61.759	11.500	20.339	1.424	4.788
	Upper 95% CI	0.646	0.581	0.604	0.472	0.540

	Lower 95% CI	0.169	0.101	0.125	-0.010	0.059
14. Allocentric	Kendall's tau	0.444**	0.437**	0.274	0.261	0.338
	BF_{10}	46.856	40.218	1.813	1.499	5.145
	Upper 95% CI	0.636	0.630	0.487	0.476	0.544
	Lower 95% CI	0.158	0.152	0.006	-0.007	0.063

Table 4.7: Bayesian Kendall's Tau Correlation between Property Generation Codes and Divergent Thinking Strategies (Matheson's Categorisation)

4.5.4.1 Modality Specificity

A MANOVA(Roy Test) was run to check if modality specificity plays a role in the distribution of codes. Modality-wise distribution of codes satisfies the multivariate normality assumption of MANOVA (Shapiro-Wilk=0.823, p=0.003). Table4.8 lists the results which shows a significant ($p<0.001$) effect of modality specificity on the code categories for Alternate Uses.

4.6 Discussion

Even though abstraction is considered to play an important role in the processes underlying creativity, there is very little work that studies the relationship between the two constructs. This work investigated the relationship between the contents or features of abstraction and creativity. To study abstraction a Property Generation task was used, where participants generated association and properties of some common words. Creativity was studied using an Alternate Uses task, where participants generated uncommon uses for some common everyday objects. There were two areas that were of interest to us: i) the content of abstractions and creative generations and ii) levels of abstraction (or generating responses with higher levels of abstraction and its relationship to creativity) and its association with creativity.

To study the relationship between abstraction and creativity, an auditory study with three tasks was conducted. A task requiring participants to rate familiarity and abstractness, a task requiring participants to generate associations that measured abstraction, and a task where they generated alternate uses which measured creativity. Abstractions are the associations, properties, or organizational structures acquired for concepts. The associations and alternate uses generated by participants were coded and frequencies used for the analysis of associations. Creativity is usually measured only on performance. To the best of our knowledge, for the first time, this work applies content coding to creative generation to examine the content or features or properties of creative generations. The creative generations were also scored on creative thinking, measured using Guilford's method.

We discuss the findings in the context of the Amodal and grounded debate on concept representation. The results from the content analysis of the two tasks will be discussed followed by a discussion on the relationship with level of abstractness and creative performance.

Traditional models of concept content and creativity would have that concepts are formed by adding information to features or taxonomic placeholders. However, the very high distribution of Situation content (refer to figure4.3) in our analysis for both concept content and creativity responses indicate that our associations are largely associations of situation which are the ”contexts where these concepts are encountered” [69]. Similarly, for creativity, Amodal theories would suggest a manipulation of entity properties or shifting taxonomies. But we seem most likely to manipulate situational content. Our results indicate that we think in terms of contexts and our personal lived experiences, rather than objective Taxonomies or Entity Properties.

The high distribution of situation content is in line with previous studies conducted to study concept content. For example, studies conducted by Barsalou and Weimer Hastings [6] and Lenci et. al. [69] showed the same trend. A further descriptive analysis of Situation responses revealed that Alternate Uses was characterised by concrete concept association and action (figure4.5) which is also in line with Embodied Theory. This also emphasises the role of action underlying our creative generations.

The Property Generation responses is characterised by ’concrete associations’ and ’abstract associations’ followed by ’space’(spaces commonly associated with a concept, e.g. swan-pond). (Refer to figure4.5.) These are contextual associations related the concept like sharpener, eraser, childhood, impermanence of pencil marks for the concept pencil. These were the responses which characterised the concept space of our participants. These findings strengthen Barsalou’s claim of concept content being situated in the specific contexts they were experienced in.

Embodied theories focus on a primary role of motor action as the basis of our knowledge structures, be it concept content, categorisation or the organisation of our semantic networks. The responses generated by participants had a lot of purely verbal based and other introspective parts as well. Quite a few of the responses for the Alternate Uses task, gave not ’uses’ in a physical sense, but uses as ”symbols” or ”for annoying a friend or sibling.” While our results mostly side with the strong embodied theory claims, we would like to rephrase action as interaction. While action phrases this idea mostly in terms of motor action, interaction captures introspective and social aspects, capturing the rich internal lives each of us leads as well.

4.6.1 Abstractness

To study abstraction a Property Generation task was used, where participants generated association and properties of some common words. Creativity was studied using an Alternate Uses task, where participants generated uncommon uses for some common everyday objects. There were three areas that were of interest to us: i) the content of abstractions and creative generations ii) levels of abstraction (or generating responses with higher levels of abstraction and its relationship to creativity) and creative ability iii) divergent thinking strategies and its relationships with content and levels of abstraction. This section discusses our findings from each of these points.

4.6.2 Concept Content

Creative thinking has been predominantly measured using Divergent Thinking and Convergent Thinking tasks, tasks to differentiate creativity from intelligence or personality and studies on genius [27][97]. These studies focus on the environmental, personality or relation to other mechanisms. However the qualitative content analysis of creative responses is still a very new area of research. We used a contextual text analysis was conducted to investigate the relationship between the concept content and the creative generations. To the best of our knowledge, there are no studies which have coded the creative generation space to analyse the content.

We observed a comparatively high distribution of situation based content for both concept content and creativity spaces (figure4.3). Situation features are features that are embedded in events, the manner, situations and contexts in which these concepts are encountered [69]. Unlike traditional Amodal propositions that argue in favour of entity properties or shifting taxonomies, we observed situation based representation for concept coding or mental manipulation for alternate uses, divergent generation tasks. Our results suggest that we think in terms of contexts and our personal lived experiences, rather than objective Taxonomies or Entity Properties.

The high distribution of situation content is in line with previous findings conducted to study concept content and representation. Concept content analysis conducted by Barsalou and Weimer-Hastings [6] and Lenci et. al. [69] showed the same pattern. These findings support non-classical, contextual [21][9] and prototype theories of concept representation [54] where concepts are characterised by contextual information rather than sets of necessary, well-defined rules and characteristics.

Directed contextual text analysis of alternate uses responses revealed that Alternate Uses was characterised by concrete concept association and action. Embodied Theory emphasises the role of action simulation in generating our creative generations [21][69]. Our findings from the analysis of concept content align with this.

Further, we observed a relevance of social construct and abstract concepts while going through the alternate uses task responses. The task asked participants to come up with ”uses” which typically refers to physical utility like using pencils to tie a bun or using a pencil in a mixer. Interestingly ”uses” were also interpreted in social and representational contexts. Participants occasionally generated uses such as using a bell to call your mother for food which will definitely annoy her, or using a statue to unsettle people. Abstract responses were along the lines of using an apple to teach alphabet or using a clock to represent time. These responses emphasise our social nature, that our ”uses” are beyond utility, that we generate things that are personal and affect our specific contexts.

Our contextual analysis distributions showed that Property Generation space is characterised by concrete associations and abstract associations followed by space (figure4.5). These are contextual associations related to the concept like sharpener, eraser, childhood, impermanence of pencil marks for the concept pencil. These were the responses which characterised the concept space of our participants. These findings strengthen Barsalou's claim that concept content is situated in the specific contexts they were experienced in [6][22].

To investigate the relationships between the concept content responses and alternate uses responses a non-parametric, Bayesian correlation was used (refer to table4.5). Results showed that Entity, Situation and Introspection type Alternate Uses (AUT) were strongly correlated with Taxonomic property generation. Situation and Introspective AUT responses correlated with Entity Property type Property Generation responses. This relationship is novel to creativity literature, and no studies have been conducted studying the relationship between the two spaces.

4.6.3 Creative Ability and Concept Content

An non parametric Bayesian correlation analysis of the relationship between creative ability and concept content was carried out. It revealed strong correlations for Originality and Fluency with Situation and Taxonomic associations (table4.4. This implies that increasing distributions of Situation and Taxonomic concept content are related with increasing originality and fluency.

Borghi et. al. (2018) [7] argue that different processes are responsible for different kinds of abstractions. The processes underlying the abstraction of taxonomic and situation information are suggested to be different [7]. Piaget's (2008) [78] theory of external and reflexive abstraction [78], Barsalou's (1999) [12] theory of perceptual simulation both advance that the processes involved in abstraction are the same processes that result in creativity. If the processes that underlie abstraction also underlie creativity, then analysis studying the processes involved in Situation and Taxonomic abstractions and creativity could reveal insights into the specific process underlying creativity.

Apart from this, Introspection correlated strongly with Elaboration (section4.5.2.1, table4.4). A possible explanation for this could be in terms of effort and focus on details, where details of internal states requires a particular sense of reflection and going into specific rich experiences. Elaboration requires generating specific details which come from specific rich experiences.

4.6.4 Levels of Abstraction

The second aim of our work was to investigate the relationship between the level of abstraction of responses generated by individuals and creative ability. Previous studies observed that abstracting the problem to higher levels of abstraction is associated with high creative thinking, especially in open ended problems like imagining a living animal on a different planet and drawing their front view [29]. It has been observed that the novel idea generation or object generation was subjected to the kind of instructions given to the participants. When participants were instructed to think specific versus abstract, they generated less versus more novel objects [29]. Kendall's Tau correlation between Level of Abstraction and creativity was conducted to study whether the average level of abstraction is related to creativity (table4.2). Strong correlations between Fluency and Originality (Tau = 0.44, BF10 = 47.19) with higher levels of abstraction support a relationship between abstraction and creativity.

However, the two other components of creativity: Flexibility and Elaboration do not have high correlations with level of abstraction, contrary to our hypothesis. A possible explanation could be that Flexibility and Elaboration demand higher cognitive efforts than Fluency. Participants responded to the Creativity Task after the Property Generation Task. Even though participants were instructed to take a break before attempting the Alternate Uses task, there could be effects of fatigue or boredom that influenced their creative generations. Ward's Path of Least Resistance model proposes that people generate common, standard solutions to problems first to preserve cognitive economy. Generating many types of responses and elaborating on fine details is cognitive heavy resulting in lower Flexibility and Elaboration.

Further, the minimum number of responses mandated by the instructions was three. While there was no upper limit, most participants generated three. Flexibility becomes more visible with larger number of responses. Our study may be limited in the complete evaluation of individual flexibility.

So far the creative thinking task has been measured using Divergent Thinking and Convergent Thinking tasks, tasks to differentiate creativity from intelligence or personality and studies on genius [27][97]. These studies focus on the environmental, personality or relation to other mechanisms. However the qualitative content analysis of creative responses is still a very new area of research. To investigate relationships between the concept content responses and alternate uses responses a non-parametric, Bayesian correlation was used. Results showed that Entity, Situation and Introspection type Alternate Uses were strongly correlated with Taxonomic associations. Situation and Introspective codes Alternate Uses responses correlated with Entity Property type Property Generation. This relationship is new to creativity literature. To the best of our knowledge, there are no studies which have coded the creative generation space with this scheme and no studies have been conducted studying the relationship between the two spaces.

A Kendall's Tau correlation was conducted between the levels of abstraction and Alternate Uses codes to understand how the creativity and concept spaces relate with abstraction (table4.3). To investigate whether there is a relationship between the general tendency to abstract at higher levels and if this can predict certain kinds of responses. Level of abstractness correlated strongly with Situation (Tau = 0.457, BF10 = 101.317) and Introspection codes (Tau = 0.511, BF10= 254.891). A possible explanation for the correlation of Introspective generations is Piaget's "reflexive abstraction" which is abstracting internally over existing concept space. People who tend to engage in reflexive thinking more often are probably more likely to generate more outcomes related to their own internal states and evaluations. The association of Situation is more counter-intuitive, while abstractness is about going further away from material referents, situation refers to specific contexts where these concepts are encountered. This is another indication of how context specificity and abstractness need not be antagonistic to each other.

Our results suggests that situation or the contexts in which a particular concept is experienced plays a significant role in abstract thinking and help in formulating abstract concepts. The situation, context, or event, lays out the relevance and reference to evaluate its functional properties than what it is made up of or which class or categories it belongs to. The results are in line with previous findings indicating support for role of context in abstract concept processing in discourse [6][62]. It has been reported that situation, context or its relevance might play more critical role in representation of abstract than concrete concepts [6]. Studies have also argued the importance of simulation in abstract thinking [12][44] and have reported the role of 'action' or 'motor' in constructing abstract concepts. As per Grounded theories of cognition, situation and the context in which the concepts are encountered defines the scope of constraint and accordingly determines the abstract thinking.

The strong association between situation and abstraction, and situation based representation of alternate uses of concepts (Creativity) and abstraction, suggest unequivocal support for role of context in concept acquisition, constructions, semantic association, and novel concepts or uses formation. The current result extends the grounded theory of cognition, suggesting that situation is not only relevant for concrete and abstract conceptual representation but also plays a key role in creative task performances as well. It also strengthens the argument in favor of experience, in which the learning, acquisition of concepts take place, has a role in abstraction as well as creative thinking [21][16].

4.6.5 Divergent Thinking Strategies

We extended Matheson's Strategy approach and present a novel mixed method of analyzing alternate uses task responses using descriptive property analyses. So far, the literature in creativity has used measures of divergent thinking and convergent thinking separately. When it comes to divergent thinking, literature has majorly employed Guilford's scoring method. Matheson's work emphasizes that Divergent Thinking has been mainly used as a diagnostic tool to estimate creative ability, but the strategies that underlie divergent generations have not been studied rigorously enough. A divergent thinking strategy scoring method which was developed by Matheson and Kennet [97] to characterise Divergent Thinking in terms of strategies used based on neurological and behavioral evidence. This scheme was used to study the relationship between abstraction and creative thinking strategies.

Abstraction ability or the level of abstraction did not correlate with any Divergent Thinking Strategy (table4.6). This was contrary to what we had expected. Matheson and Kennet [97] found that generating specific, concrete simulations and mapping it onto different domains play an important role in alternate uses. If this is the case then simulating specific exemplars is in contrast to Abstraction ability which is the ability to generate higher levels of abstraction. In this light, our results make sense. However, these results indicate that embodiment theories have to explain abstraction to explain what an embodied creativity looks like.

To investigate any relationships between concept space and Divergent Thinking strategies, the Divergent Thinking scores were correlated with Property Generation scores (table4.7). We found that Situation correlated strongly with whole (Tau = 0.4, BF10 = 66.87), different action (Tau = 0.5, BF10 = 465.7), away from the body (Tau = 0.5, BF10 = 205.8) and familiar uses (Tau = 0.46, BF10 = 101.3). When experiencing things in their contexts, objects are experienced as wholes and are often away from the body. Therefore, in hindsight this correlation makes sense. Correlation with both familiar and different action is less intuitive.

Taxonomy correlated with action, wholes, same, concrete, familiar, towards, egocentric and allocentric divergent thinking strategies. Entity correlated with action, whole object, towards the body, same action, concrete, egocentric and allocentric. These strategies where particularly chosen to "capture dimensions of simulations of body" during Divergent Thinking tasks. Participants with high Entity Property and Taxonomic content tended to view uses as literal functional uses rather than abstract uses. Their responses often used factual elaborations like, "apple is supposed to be good for skin, therefore we can use it as a face mask," or "hammer can be used as a paperweight, because its heavy" or "we can see light reflections on a window therefore it can be used as a mirror. " Factual details use whole, concrete, often known uses, possibly explaining this correlation. These results are also contradictory to Matheson et al.'s findings, where taxonomy and entity properties do not necessarily refer to highly specific, concrete, simulations of possible actions to a new domain.

4.6.6 Limitations

The online, remote model was challenging to work with. Participants had network connectivity problems resulting in bad audio recordings, a large chunk of which had to be discarded. Due to the pandemic, this was unavoidable. The number of responses that remained limited our sample size. Results need to be interpreted in caution and replicated for these results to be standardised.

The online model also meant that the experimenter was not present in person. Not being present in person to clarify any questions immediately and the seriousness that comes from in person presentation meant that there are stronger effects of boredom and lower motivation in the responses. While these factors have definitely affected the quality of responses, overall most participants responded with sincerity. We designed our tasks to flow one after the other, because we wanted participants to generate associations and properties of the object before generating alternate uses for the words. However, the length of the tasks may have resulted in fatigue which may have affected the quality of responses.

4.7 Conclusion

If creativity comes from existing knowledge then existing knowledge should shape creativity. Existing knowledge is acquired through our knowledge acquisition process involving our sensorimotor systems. To fully understand creativity a systematic examination from our acquisition processes upto to creativity is required. However, the processes of knowledge acquisition and creativity have not been studied together. This work explored the relationship between abstraction and creativity.

To study the relationship between abstraction and creativity, an auditory study with three tasks was conducted. A task requiring participants to rate familiarity and abstractness, a task requiring participants to generate associations which measured abstraction and a task where they generated alternate uses which measured creativity. Abstractions are the associations, properties or organisational structures acquired for concepts. The associations and alternate uses generated by participants was coded and frequencies used for analysis of associations. Creativity is usually measured only on ability. To the best of our knowledge, for the first time, this work applies content coding to creative generation to examine the content of creative generations. The creative generations were also scored on creative ability, measured using Guilford's method and categorised on a list of Divergent Thinking Strategies developed by Matheson et. al. (2020). The associations were also scored on level of abstraction.

In the analysis of content, we found very high distribution of Situation content which are the contexts in which the concepts is encountered. This is interesting because it questions the Amodal paradigm which focuses on abstracting properties and taxonomies rationally. However, our content analysis suggests a more ad-hoc, experience based abstraction. Furthermore, the high prevalence of Situation content in the creative generations shows that this experience based understanding is what is used in higher cognitive functions as well.

The level of abstraction was of particular interest to us. We found a strong association between higher levels of abstraction and originality and fluency indicating a relationship between abstraction and creativity. However, we did not find any significant relation between higher levels of abstraction and divergent thinking strategies.

While it is difficult to establish concrete relationships between these processes with our sample size, the small sample size also allowed us to examine responses closely and qualitatively code the data in a way that would not have been possible with larger sample sizes. More studies in this area are required to be able exactly establish the relationship and interaction between these processes. This work suggests and points to interesting directions for research, questioning our imagination of creativity.

Cases	df	Approx. F	Largest Root	Num df	Den df	p
(Intercept)	1	30.736	9.457	4	13.000	$<$ .001
Modality	2	3.184	0.910	4	14.000	0.047
Residuals	16					

Table 4.8 MANOVA: Roy Test for modality specificity in Alternate Uses

Chapter 5

Conclusions, Implications and Future Directions

The exact processes that underlie creativity are still not fully understood. Despite acknowledging that creativity has to come from existing knowledge, the concept space and processes involved in its formation have not been studied along with creativity. This work explores the relationship between the processes of abstraction and creativity. Abstraction is the process through which concepts are formed. To examine this relationship, two studies were conducted: i) studying variance in the perception of abstractness ii) the relationship between abstractness and creativity.

In studying the perception of abstractness, participants rated familiarity and abstractness on 5-point Likert Scales. Words were selected based on familiarity, levels of abstractness and modality dominance (or how strongly a word is experienced through one modality) from three publicly available datasets. Eighty selected words were normed for familiarity and abstractness. Preliminary analysis emphasised the heterogeneity in the perception of abstractness where not all participants perceived highly abstract words as abstract, but most participants perceived concrete words as concrete. Some accounts on the representation of abstractness argue for a binary model of clearly demarcated abstract and concrete bubbles. Whereas others argue for a spectral, continuous one. Our findings lie somewhere in between where concrete words are clearly concrete but abstract words are much fuzzier.

For our primary investigation two auditory tasks were conducted. Participants were asked to generate associations, properties and what they understand by the words during a Property Generation Task which was used for studying abstraction. They generated weird and alternate uses for a Divergent Thinking Task which is commonly administered for studying creativity. A qualitative directed, contextual analysis was used to code the spaces. We hypothesised that if participants have a higher level of abstraction they will have higher creativity. We expected our exploratory analyses on the spaces to reveal several correlations between the two spaces and between abstraction and divergent thinking strategies.

Traditional Amodal Symbol models of concept content and creativity proposed that our concepts are formed by adding information to placeholders of features or taxonomic information [20][12]. Our results emphasise the role of individual, specific experience. The context, place, what was around it, how we experienced it, what we were feeling at the time and what we were taught form the basis of our concepts. and not just entity qualities and hierarchical marking all as traditional concept theories would have us understand. What makes up our concepts also make up our creativity. We found that abstraction at higher levels correlates strongly with originality and fluency.

We found that the concept content for both is context specific, contrary to traditional amdodal models of concept representation and in support of Grounded Theories of concept representation. We found very similar patterns in the Property Generation task to existing literature examining concepts from a grounded perspective. The creative space has never been coded for content before. This work finds that the creative space is also highly characterised by situation content in support of the Grounded Theories. This is especially significant, because creativity poses a problem for grounded theories is terms of explaining the process that traditionally is thought to use higher order abstractions and functions beyond simulation. Our findings find a high situation content in divergent thinking responses supporting a grounded claim.

The strong association between situation and abstraction, and situation based representation of alternate usage of concepts (Creativity) and abstraction, suggest unequivocal support for role of context in concept acquisition, constructions, semantic association, and novel concepts or usage formation. The current result extends the grounded theory of cognition, suggesting that situation is not only relevant for concrete and abstract conceptual representation but also plays a key role in creative task performances as well. It also strengthens the argument in favor of experience, in which the learning, acquisition of concepts take place, has a role in abstraction as well as creative thinking [12][7].

The other mechanism that is not well explained by Grounded theories is the levels of abstraction from low to high. As a process, the process of abstraction just as abstracting from experience to form meaningful objects in our thought and its relationship with creativity has not been well examined despite several accounts suggesting the role of abstraction in creativity. Unlike the traditional linear input-output models of cognition, several of these accounts propose that the same mechanisms involved in abstraction are involved in creativity. Therefore we expected levels of abstraction to not necessarily, but sufficiently predict creativity. We found strong correlations between level of abstraction and originality and fluency.

However, contrary to what we expected, there was no significant correlation between the level of abstraction and Divergent Thinking Strategies. This means that in our sample, generations of more abstract associations did not predict the use of any of the Divergent Thinking Strategies.

Divergent Thinking Strategies and Abstraction space revealed several strong relationships, especially with situation, taxonomic and entity property content with several strategies. This shows the potential for content to predict ways of divergent thinking.

While traditional models position existing knowledge as a hamper to creative thought because of the way originality is viewed, I would like to question this line of thought. From an evolutionary perspective, being able to solve problems relating to our specific contexts is useful as opposed to coming up with ideas that are unheard of. I would like to position creativity as finding apt solutions, where creativity is both original and valuable. Previous theories say that old knowledge hampers creativity. Our work shows that both the process of acquiring knowledge: abstraction and contextual knowledge are connected to the creative process. The collection of our experiences provide constraints and a framework for directing creativity. It is not a hamper, but something that aids and forms the foundation of the creative process. While further research is required to establish the exact mechanisms that are in play during abstraction and creativity explaining the exact interaction between the two resulting in creative generations, our work suggests that both the process and content of abstraction form the basis of creative thinking.

5.1 On the Future

For future studies we intend to modify the question for better responses. A “take time to think of answers” could be used instead of a free generation “what comes to mind first” instructions. Here, people are pushed to think and generate their responses rather than give the first responses which come to mind [69]. It will be interesting to see how the generations are different or not with more intentionality.

The stimuli used were taken from an Italian and German database. The Property Generation task and Alternate Uses task which demand very subjective experience should be affected by cultural differences. It is in the interest of this researcher to study how culture shapes concepts.

Appendix A

Supplementary Material

A.1 Responses and Coding

Subject ID	Concept	Response	Codes	Subcodes
132576	apple	doctor repellent	S, T	eab, isa, sc, eco,
132576	apple	recreational vehicle for a worm	S, T	eco, isa
132576	apple	gravity discovering object	S, T	eab, isa, eco
132576	hammer	to pretend that you are Thor	S, I, T	eco, eva
132576	hammer	a tool to hit your fingers when a nail is holding them	S, T	act, eco, isa
132576	hammer	a very risky frisbee	I, S, E, T	eva, eco, pnp, isa

Table A.1 Responses for two concepts given by a participant during the Alternate Uses Task. The third column called Codes lists the content analysis code categories given by three judges to each response. The codes are a concatenation of all codes given by the judges. The fourth column called ”Subcodes” gives the subcodes given to each response by the three judges.

A.2 Wilcoxon Test for Differences between the Sets

	V	p
Abstractness_individual	406.000	$< .001$
Situation_AU	406.000	$< .001$
Taxonomy_AU	78.000	0.002
Introspection_AU	21.000	0.034
Quantity_AU	3.000	0.346
Entity Property$_{A}U$	253.000	$< .001$
Taxonomy_Pgen	406.000	$< .001$
Entity Property_Pgen	406.000	$< .001$
Situation_Pgen	406.000	$< .001$
Introspection_Pgen	351.000	$< .001$
Quantity_Pgen	15.000	0.059

Table A.2 Table showing the results of a Wilcoxon Signed Rank Test for all scoring variables, between the two stimuli sets. This shows that there were no significant differences in the behaviour of participants between the two tests from different words being selected. Therefore, the stimulus selection is internally consistent and both sets can be treated as a whole.

A.3 Supplementary Correlational Analyses

Variable		Fluency	Flexibility	Originality	Elaboration
1. Taxonomy_AU	Kendall's tau	0.139	0.073*	0.166	0.284
	BF_{10}	0.409	0.281	0.510	2.092
	Upper 95% CI	0.367	0.308	0.391	0.49
	Lower 95% CI	-0.117	-0.176	-0.092	0.014
2. Entity Property_AU	Kendall's tau	0.367*	-0.028	0.309*	0.228
	BF_{10}	8.893	0.248	3.131	0.975
	Upper 95% CI	0.569	0.217	0.518	0.446
	Lower 95% CI	0.089	-0.267	0.037	-0.037
3. Quantity_AU	Kendall's tau	-0.145	0.000*	0.043*	0.000*
	BF_{10}	0.428	0.243	0.255	0.243
	Upper 95% CI	0.111	0.242	0.280	0.242
	Lower 95% CI	-0.373	-0.242	-0.204	-0.242
4. Situation_AU	Kendall's tau	0.662***	0.152	0.629***	0.284
	BF_{10}	27775.055	0.452	9145.603	2.112
	Upper 95% CI	0.812	0.379	0.788	0.497
	Lower 95% CI	0.351	-0.105	0.323	0.015
5. Introspection_AU	Kendall's tau	0.337*	-0.028	0.271	0.281
	BF_{10}	5.078	0.248	1.747	2.001
	Upper 95% CI	0.543	0.216	0.485	0.493
	Lower 95% CI	0.062	-0.268	0.003	0.012

Table A.3 Bayesian Kendall's Tau Correlations between individual creativity scores and Alternate Uses codes

Variable		Fluency	Flexibility	Originality	Elaboration
1. isa	Kendall's tau	0.422**	-0.033*	0.290	0.236
	BF_{10}	28.104	0.250	2.291	1.086
2. coo	Kendall's tau	0.008*	0.119	0.092	-0.219
	BF_{10}	0.244	0.356	0.305	0.882
3. exa	Kendall's tau	0.224	0.172	0.228	0.544***
	BF_{10}	0.933	0.538	0.982	641.441
4. syn	Kendall's tau	-0.064*	-0.169	0.043*	-0.191
	BF_{10}	0.271	0.523	0.255	0.647
5. ant	Kendall's tau	-0.223	-0.007*	-0.021*	-0.064*
	BF_{10}	0.920	0.244	0.246	0.271
6. ins	Kendall's tau	0.225	0.336*	0.275	0.185
	BF_{10}	0.945	4.985	1.842	0.610
7. mer	Kendall's tau	0.257	0.123	0.228	-0.105
	BF_{10}	1.422	0.366	0.981	0.326
8. hol	Kendall's tau	0.173	0.003*	0.244	-0.089*
	BF_{10}	0.541	0.243	1.202	0.301
9. mad	Kendall's tau	-0.096*	-0.017*	-0.051*	0.283
	BF_{10}	0.311	0.245	0.261	2.064
10. ppe	Kendall's tau	0.337*	0.024*	0.324*	0.064*
	BF_{10}	5.110	0.247	4.005	0.271
11. pnp	Kendall's tau	0.371*	0.022	0.250	0.298
	BF_{10}	9.601	0.246	1.296	2.612
12. eve	Kendall's tau	0.332*	-0.014*	0.289*	0.278
	BF_{10}	4.636	0.244	2.266	1.927
13. eab	Kendall's tau	0.521***	0.360*	0.499***	0.212
	BF_{10}	338.096	7.854	184.971	0.812
14. eco	Kendall's tau	0.221	0.219	0.379**	0.246
	BF_{10}	0.900	0.881	11.268	1.235

Table A.4 Bayesian Kendall's Tau Correlations between the Property Generation Subcodes and Guilford Scores for creativity

Appendix B

Instructions and List of Stimuli

B.1 Wordlist Used for Norming

Properties	Type
sore	Tactile
itchy	Tactile
to_stroke	Tactile
pineapple	Tactile
swan	Tactile
cherry	Tactile
knife	Tactile
cat	Tactile
kiwi	Tactile
apple	Tactile
comb	Tactile
to_touch_lightly	Tactile
muscle	Tactile
mosquito bite	Tactile
shawl	Tactile
chirping	Auditory
screeching	Auditory
memory	Auditory
fright	Auditory
distraction	Auditory
talent	Auditory
attraction	Auditory
apartment	Auditory

Table B.1 continued from previous page

woods	Auditory
hammer	Auditory
shop	Auditory
beach	Auditory
metro station	Auditory
grandmother	Auditory
television	Auditory
model	Visual
creativity	Visual
danger	Visual
fitness	Visual
banana	Visual
pencil	Visual
crow	Visual
sea	Visual
to_spot	Visual
to_glimpse	Visual
to_peep	Visual
white	Visual
glamorous	Visual
headlight	Visual
lawn	Visual
to_hate	Internal State and Emotion
thought	Internal State and Emotion
compassion	Internal State and Emotion
astonishment	Internal State and Emotion
wonder	Internal State and Emotion
pain	Internal State and Emotion
to_fear	Internal State and Emotion
to_massage	Internal State and Emotion
will	Internal State and Emotion
passion	Internal State and Emotion
apology	Internal State and Emotion
disappointment	Internal State and Emotion
frustration	Internal State and Emotion
resolution	Internal State and Emotion
nightmare	Internal State and Emotion

Table B.1 continued from previous page

order	Abstract
lust	Abstract
tradition	Abstract
hunger	Abstract
horror	Abstract
insight	Abstract
fight	Abstract
terrorism	Abstract
custom	Abstract
elegance	Abstract
performance	Abstract
nervousness	Abstract
carefulness	Abstract
hope	Abstract
effort	Abstract
darkness	Abstract
party	Abstract
culture	Abstract
matter	Abstract

Table B.1: List of words used in the Ratings Task described in Chapter 3.

B.2 Word List used in the Property Generation and Alternate Uses Tasks

Set -A			Set-B		
Word	**Modality**	**Concrete/Abstract**	**Word**	**Modality**	**Concrete/Abstract**
pencil	visual	concrete	banana	visual	concrete
white	visual	concrete	To spot	visual	concrete
window	visual	concrete	staircase	visual	concrete
creativity	visual	abstract	danger	visual	abstract
hammer	auditory	concrete	pan	auditory	concrete
bells	auditory	concrete	television	auditory	concrete
beach	auditory	concrete	apartment	auditory	concrete
memory	auditory	abstract	attraction	auditory	abstract
apple	tactile	concrete	cherry	tactile	concrete
comb	tactile	concrete	knife	tactile	concrete
swan	tactile	concrete	cat	tactile	concrete
mosquito bite	tactile	abstract	To stroke	tactile	abstract

Table B.2 Words used in the Property Generation Task

Set-A		Set-B	
Word	**Modality**	**Word**	**Modality**
pencil	visual	banana	visual
window	visual	staircase	visual
statue	visual	diamond	visual
hammer	auditory	pan	auditory
bells	auditory	television	auditory
stopwatch	auditory	Guitar string	auditory
apple	tactile	cherry	tactile
comb	tactile	knife	tactile
kiwi	tactile	shawl	tactile

Table B.3 The list of words used in the Alternate Uses Task

B.3 Instructions

B.3.1 Property Generation

You will now begin the actual task. You are required to give AT LEAST FIVE responses for each concept.
Please respond as sincerely as possible because this is part of a larger body of my research work.
You are required to respond by speaking about the first thoughts, properties and associations that come to your mind regarding the concept.
Try to respond as spontaneously as possible. Avoid repetitions and synonyms (two words that have the same meaning like forest and jungle).
To replay the word press 'r' or 'R' on keypad. Press SPACE when done recording.

B.3.2 Alternate Uses

After the beep you may start speaking out loud, as many unsusual, weird and uncommon uses as you can think of, for the object you just heard. Press SPACE when you are done to stop recording and go to the next word.

The more creative or outlandish your responses the better!

Please generate AT LEAST THREE responses per word.

B.3.3 Ratings

FAMILIARITY Familiarity refers to how well you know, understand and can explain the word. You will be rating on a five point scale. 1 = word you have never heard of before, 5 = very familiar word. To rate, mark your rating on the scale. Press SPACE to move next.

RECORDING RESPONSE
After Familiarity rating, you will hear a beep indicating the recording has started. You may now freely speak the first thoughts and associations that come to you about the concept you heard. Press SPACE when done.

ABSTRACTNESS SCALE
Abstractness is opposed to concrete. Concrete concepts can be directly sensed through your five senses, i.e touch, taste, smell, hearing and vision. Concepts like fan, Mango tree and book are highly concrete concepts. Concepts like joy, liberty and truth are abstract concepts. 1= highly concrete, 5= highly abstract and 3= not sure.

Keys Recap:
Press 'r' or 'R' to replay the word. Click '1', '2', '3', '4' or '5' on scale to rate. Press SPACE to finish recording. Press SPACE to go next.

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