Department of Psychology

Cognitive Psychology in Crisis: Ameliorating the Shortcomings of Representationalism

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Abstract

Traditional cognitive psychology relies on concepts bordering idealism, an issue that has been known since the end of the 19th century. At best, the underlying assumptions are misleading and do not bring us closer to an understanding of human enterprise. Also, psychology in general is not a unified paradigm; its sub-disciplines rely on different conceptual bases. Ecological Psychology can change that. Getting rid of the non-sequitur “it is all in the brain” is a start and not that controversial, but, this is simply a stepping stone to a complete change in perspective. Organisms are born into an ever-changing environment, which they constantly interact with, perceive themselves in, constantly change and are changed by. An attempt is made to contrast computational and ecological assumptions about how the brain works by having participants intercept an object on a computer screen. Hypothesis is that participants will favour an ecological strategy over a computational. Results speak in favour of reliance on ecological assumptions rather than computational and also indicates that representations may not be necessary even for objects that are temporarily imperceptible.

Keywords: cognitive psychology, representationalism, ecological psychology, virtual interception task

Introduction

Contrasting computational assumptions about the function of the brain with ecological assumptions requires thorough investigation of why we need to abandon traditional cognitive psychology and replace it with ecological psychology. The thesis also breaks new experimental ground within this perspective by challenging the assertion that our brains function computationally and that depictions cannot be used in ecological psychology research. There is thus a need to understand why traditional cognitive theory is inadequate to explain human behaviour and explicate central concepts in the theory to replace it, before heading into the details of the experiment.

The psychological disciplines have held strongly to the ideals of logic and mathematics in a historical perspective. It may have brought solace to stick to truth-tables, hard science doctrine and other ideals since we thought of them as true. The issue has been that it only served to perpetuate anthropocentrism, effectively misleading theory. The hard sciences will always have a bearing on how psychological science is grounded, but, in order for psychology to move out of its dark ages it is time to change perspective on human behaviour. It is questionable whether truth-tables and abstract philosophical logic are the ideals on which human behaviour should be judged. Reliance on other disciplines to define psychology enforces a framework not developed for the study of human behaviour. However, organisms have access to the ecological world (Gibson, 1986), and on a daily basis, we decide, think, act, *live* on that level. Defining the psychological domain on the basis of *what* organisms do and *where* we do it, is more appropriate. Radical Embodied Cognitive Science, built on the basis of Ecological Psychology, provides a discipline-wide unification sorely needed to finally unite psychology into a paradigm.

Staying within the realm of cognitive psychology does not easily allow for criticising it, instead a meta-perspective will be utilised for this purpose. Additionally, introducing another perspective creates a reference point, allowing comparison of theoretical frameworks. The philosophical basis and experimental methodology will be critiqued and arguments presented which will illuminate its critical flaws, unwanted consequences and most importantly, reveal the often overlooked, misleading assumptions. On this basis, the conclusion is that cognitive psychology perhaps *should* see itself as in crisis. An alternative theoretical framework will be proposed, explicating its underpinning and assumptions. A brief modification to research presentation and guidelines will be proposed, an original piece of research based on ecological assumptions will be presented, along with pivotal future research.

Arguments Against Representationalism

An attempt will be made to outline the representationalist assumptions, conceptual framework, and present examples of how it has refuted other approaches to human behaviour. A strong focus will be maintained on the issues with the grounding framework of representationalism and the idea that everything is represented in our brain. Examples and reasoning will be presented of how most of the evidence for representationalism is doubtful and will illuminate the falsities and fallacies one is subject to when working under the assumptions of this perspective.

Don't Panic

Before heading into the criticism of representationalism, it is worthwhile to situate it in history, as it is derived from overarching theories and diverge from others. Theories of mind in the traditional cognitive literature lead to two main stances, eliminativism and representationalism. Representationalists take direct perception[1] to heart, that is, we can directly perceive the environment around us, whereas eliminativists do not take the mind to be a mirror of nature (anti-representationalists). This is the first main division on theories of mind and cognition; there are those who think the main business of cognition is the construction, manipulation and use of representations of the world and there are those who believe that it is to do with something else (Chemero, 2007). This division stems from empirical experimentalism at the end of the 19th century, where two experiments could have opened up contradictory fields, unfortunately, one was ignored. Titchener (1895), a structuralist, posited that mental acts have the following structure: Firstly, caused by physical stimulation of receptors, there is a stimulus, then there is a linear series of mental acts and lastly there is a behavioural response. However, which mental acts actually occur, and in which order, is for the experimenter a matter of speculation. Suppose that we have behaviour A and B, where A is assumed to require mental acts M1, M2, M3 and M4, and B assumed to require M1, M2 and M4. By structuralist logic we could then determine the duration of mental act M3 by subtracting the time it takes to perform B by the time it takes to perform A. To do psychology then, Titchener argued, one must focus on the structure of mental acts in the series and not on their function. Dewey (1896) describes this structuralist assertion as a "reflex arc"[2] and that it is subject to "the empiricist fallacy" because of the assumption that

[1] But not in the same sense that Ecological Psychology does. Representationalists acknowledge that we can see the world for what it actually is, but for example meaning is added on later inside our brain. Ecological Psychology posits that even meaning is directly perceived in the environment.

[2] The reason he called it this was because the process begins in the body, ascends to the mind and then returns to the body in a linear, isolated fashion.

the parts are prior to the whole. Dewey argues instead that all actions, from simple reactions to the highest mental cognitions, are *organic circuits* that cannot be understood by dividing them up into parts. Out of context, a part of an action lacks any meaning and is instead seen as a “series of jerks”. The “empiricist fallacy” is however extended even further in contemporary cognitive psychology to that of naming unobservable events. More on this later. Already between Dewey and Titchener then, as early as the end of the 19th century, there are reasons to stay agnostic about the propositions stemming from Titchener’s assumptions. It should be noted that all of M1 through M4 are *assumptions* about *unobservable events* and perhaps even more so, a simplification of unobservable events based on assumptions about what the brain *does*. These assumptions do give an *explanation*, and looking at the state of contemporary cognitive psychology, it seems to be a pervasive proposition. That this explanation does not really *explain* human behaviour, due to it only containing assumptions, is a matter dealt with later. Taking a leap forward, to contemporary psychology, representationalism eventually grew from Titchener’s ideas. It has stood strong against other approaches to mind by both a vast literature using its concepts and through arguments against other approaches. The latter can generally be done in two ways, either by discussing alternatives or constraining and suppressing any other alternative except one’s own. Unfortunately, it has not been uncommon to take the latter route, for example Fodor and Pylyshyn’s argument against connectionism (1988). This can become an issue if one relies too heavily on such arguments and a specific example is presented here; Chomsky’s (1959) verbal learning argument.

- Children uniformly and rapidly learn language, without specific reinforcement.
- Children are presented with evidence insufficient to infer the characteristics of the grammar they attain in learning language.
- Learning language is the attainment of a grammar, an internal deductive mechanism that allows the recognition and production of appropriate sentences.
- Therefore, the grammar must be largely innate.
- Therefore, any theory that does not posit such an innate grammar cannot account for language learning.

Chomsky’s argument follows what Chemero calls a Hegelian argument, an argument which is marshalled in an attempt to constrain empirical research and close down developing research programs. He also posits that these types of arguments are taken very seriously in the discipline and that this is an important difference between cognitive science and other sciences, which are more purely empirical. There is a theoretical contrast, for example, between the digestive system and language learning. Chemero (2007) suggests that our knowledge of the diverse types of vertebrate digestion could not have come from armchair reasoning and argument. We could not have deduced that microbes and swallowed stones are crucially involved in digestion. The knowledge we have of digestive diversity has come about through patient empiricism over centuries of research, and psychology has yet to receive such a foundational base. Chemero puts it down to that digestion, eating and excreting, is a mere animal behaviour whereas cognition is treated as the pinnacle of evolution (herein referred to as anthropocentrism). This enforces an arbitrary point, but has a powerful consequence in that it heightens the credit lent to psychology, a discipline often under fire from other disciplines in being non-scientific (see, for example, Wai, 2012). We are special because we deal with special things. This is most definitely not the case however, it is solely the remaining tip of historical anthropocentrism: Psychology had to define itself away from other disciplines when it was institutionalised at the turn to the 20th century. In America we were trampling on medical science fields and coupled with religious influence, the human was defined different to all other animals. Once separated from religion and the emergence of biology as a foundation for our anatomical body, dualist notions concerning human enterprise began dissipating. Unfortunately however, all that happened was that the boundary moved from body to brain[3] (for the historical context of anthropocentrism, see Wampold, 2012).

There thus seems to be a reliance on people willing to act as experts and define direction of research through Hegelian arguments. Coupled with anthropocentrism, the arguments are ostensibly convincing. They also rely on philosophical bases which may be difficult to critique, it is therefore of central importance to do just that.

Hegelian Arguments and Theory-Ladenness

The cognitive discipline is maintained in part by Hegelian arguments that constrain the area of study and serve to perpetuate the fallacy that the brain does extraordinarily complex things. Chomsky’s verbal learning argument in the previous paragraph stands as an example of the former because of its second conclusion “any theory that does not posit such an innate grammar cannot account for language learning”. This essentially states that any other alternative is useless to even pursue because Chomsky has decided what and in which way something exists. An indication of this leading us astray can be found by returning to the comparison between medieval theories of digestion with contemporary cognitive theories;

[3] An intermediate step was the separation of body, mind and brain, which in part emerged from, still, dualistic notions.

both approaches to their subject matter lack a unifying set of conceptual principles and to some degree experimental methodology[4]. Kuhn (1962) defined this approach, when existent, a paradigm. When not, it encourages and allows Hegelian arguments, resulting in an all too narrow field that doesn't allow for alternative interpretations. This, in turn, leads to a thickly theory-laden approach to experimentation and is not problematic in and of itself; rationalisation of empirical observations should be guided by theory. It turns into an issue however when there is no realisation on behalf of theorists that a theoretical filter biases assumptions and interpretations in experimentation. If we assume that everything goes on *in there*, then we will only look in the brain and consequently interpret results on that basis also. To add to this, Hegelian arguments disallow alternative interpretations outright and so perpetuates an ignorant theory-laden perspective. A reason for leaving such a constrained approach to the subject matter of psychology comes from (pre-anarchist) Feyerabend (1963, 1965). According to him, having competing theories enhances those theories by forcing theoretical development to deal with the findings of rival perspectives. A contemporary example of the importance of this is the detection of mirror neurons (see Rizzolatti & Crighero, 2004, or Uddin, Iacoboni, Lange & Keenan, 2007, for a debate). Taking an alternative stance, Barrett (2011) proposes that they are difficult entities to account for without representations, but considering that Hegelian arguments lead to a theory-laden perspective, then the function of newly found entities can only be interpreted through dogmatic reasoning. Mirror-neurons were subject to this, however, all that has been observed is that they are active both on perception of others' movement and the same movement conducted by oneself. This finding is not contrary to ecological psychology for example, but the explanations given, and research on, link them with representing the outside world in the brain. There is however not enough evidence to solidify the representationalist proposals of the function of mirror-neurons (Barrett, 2011, p. 187) and their function has been severely dialled down since their discovery. Instead, ignoring what contemporary cognitive theory forces us to believe, what could explain their function? It may just be simultaneous activation between stimulated sensory modalities and/or movement, and due to strengthening of simultaneous neuronal activation, they are just more so activated, or activated in different ways, than other neurons due to their multiple sources. Explanations like these are more than discouraged due to Hegelian arguments and theory-laden contemporary cognitive psychology. But, one does not *need* to invoke representing the whole world in our brain to

[4] They are founded on the same misconception however, the Empiricist Fallacy, more on this later.

explain even mirror-neurons. Hegelian arguments thus cannot be allowed to lead to pre-emptive weeding, likely to take the paradigms-to-be along with fake starts (Chemero, 2007). Unfortunately this was the fate of Dewey and his followers and it may have led us down a garden path for just over a century.

Conceptualisation of Representationalism

Pivotally, the Representational Theory of Mind needs to be presented at this point, before continuing with the criticism of its theory-specific problematic assumptions. Fodor (1981) defines it as follows;

1. Propositional attitude states (e.g. beliefs and desires) are relational.
2. Among the relata are mental representations.
3. Mental representations are symbols: They have both formal and semantic properties.
4. Mental representations have their causal roles in virtue of their formal properties.
5. Propositional attitudes interact their semantic properties from those of the mental representations that function as their objects.

This is to say that thoughts are propositional attitudes, relations between people and mental representations stand for the semantic properties of things in the world. It follows from this that any theory that takes cognition to involve semantically evaluable internal entities is a variety of Fodor's Representational Theory of Mind (Chemero, 2007). Where contemporary cognitive theories do differ however, is in how the symbols are proposed to exist; how they are *used* in cognition. Computational Theory of Mind (Hobbes, 1651) holds that rational thought is the processing of internal symbols that represent external objects. These are then processed according to rules yielding rational thought, when applied correctly. Hobbes mental computation is literally addition, whereas contemporary computationalists say that computation is the rule-governed manipulation of formal symbols. Fodor named this Language of Thought and posited that formal symbols share many properties with idealised natural language words. That is, they are discrete, context-independent and able to be combined into larger molecular representations. Their meaning is a function of the constituent parts (Chemero, 2007). A major issue for these kinds of assertions is their strong reliance on theoretical entities, a matter dealt with later, but an indication of this can be seen in projects like CYC and DARPA. These projects attempted to program mechanisms of learning in computers by "reading" text and building an encyclopaedic type of database with formal rules. They failed, and the assumption is that they did so because common sense requires interaction with the real world (Pfeifer & Bongard, 2007). Because of the unfounded assumption that language is an abstract symbolic system following laws of grammar, we came to the false conclusion that it would be easy to construct what was supposedly so easily accomplished in our brain. Under a representationalist understanding of human enterprise, it really should have been simple, and justified, to put resources to projects like these. When failed, it should have given some indication on that perhaps underlying theory is not correct in its assumptions.

Consequential Issues of the Empiricist, and Other, Fallacies

An admittedly rough, popular contemporary methodology (but there are obviously many different ones, they all contain the same issue however) has it that we observe a behaviour A, manipulate, then observe behaviour B and lastly draw inferences about what is happening in the brain (on the basis of, often antecedent, assumptions) in the time-frame between A and B. Severe issues underlie this methodological framework, and we begin with that of assuming unobservable processes.

A person is led into a room, seated and asked to read a list of words. After some time, the same person is asked to write down as many of the words as possible. The conclusion to this type of experiment is that the invisible process underlying the explanation of recall is called memory, and consists of representing the words in the brain, storing them, to later pull them out and write them down. The sensory input must fuse in some fashion with the already stored images, or the sensory input is assimilated to a composite memory image, or it is assimilated to a class, a type, a schema, or a concept. Every single new sensory input must be categorised, assigned to its class, matched to its type, fitted to its schema and so on. However, categories cannot become established until enough items have been classified, but items cannot be classified until categories have been established. This difficulty has led to the supposition that classification may be a priori and we have innate or instinctive knowledge about the world. Gibson (1986) argues that the fallacy lies in assuming that because inputs do not convey knowledge, they can somehow be made to yield knowledge through processing. Knowledge must come from somewhere, but the mentioned reasons all beg the question. Knowledge of the world cannot be explained by supposing that knowledge of the world already exists. “All forms of cognitive processing imply cognition so as to account for cognition” (Gibson, 1986, p. 253). Also, memory (based on the idea that everything exists in our brain), is problematic, amongst other reasons, because it is devilishly difficult to falsify. Popper (1963) had the idea of theories to be non-scientific if any result could be explained in terms proposed by the theory. Posit that a participant in the above experiment does not write down any, or very few, words. Is the theory to blame and a rejection of representationalism in order? No, and in all honesty, it would not be justified to do so because the participant’s result does not directly falsify the claim. The first issue with this is that empirical observation cannot falsify the claim, and secondly, it cannot falsify it because the claim does not strictly deal with what is observed, but rather, what is not. It would be claimed that the participant failed, but not only, also the claim would be made that the participant failed to live up to the *already assumed* unobservable process posited to exist. This is by definition a central issue of theory-ladenness (see Hanson, 1958). It comes about by the assumption that our brain represents everything in the world, and we go about testing that by observing if participants live up to this ideal. But, if we are looking for a storehouse memory, we then create storehouse hypotheses and explain both success and failure in terms of storehouse memory (Chemero, 2007, and Barrett, 2011). How can a methodology be accepted that, without anything else to refute alternative explanations on than Hegelian arguments, posits an *unobservable* process to exist and then compare any observable behaviour to live up to its presumptuous ideals? Instead, the question needs to be, what is it that actually is observed? There are two behaviours, reading the list and writing down words previously on that list. Everything else is an assumption. What happens during that which we are *not* observing? A much more critical evaluation than is currently being enforced is needed. Especially when a main reason is that popular assertion, anthropocentric perspective of the brain, drives it (Barrett, 2011).

A Meta-Perspective on Criteria for Human Rationality

Gigerenzer (2008) clarifies the issue of idealised criteria for human rationality by bringing in ‘Laplace’s Demon’. He begins by asserting that we can understand the nature of sapiens by four different, distinct perspectives and the idea is to look at the way these shape theories of human rationality. The first perspective assumes omniscience, omnipotence and determinism, given to Laplace’s Demon results in a secularised version of god that knows past, present and future through deductive logic, and, allows humans to construct as-if theories of *unbounded rationality*. This is an obvious extreme point of perspective, as it has not received any empirical support that humans would be capable of. If determinism is denied for any given situation where rational thought is proposed to be needed, optimization can instead be invoked. The idea is that we make errors but we can find the most optimal strategy, and this is used in, for example, consequentialist theories of moral action; we need to take all consequences of all possible actions for all involved and calculate which action gains the most utility (thus resulting in a form of utilitarianism, see Mill, 1906). A brief, concrete example would be that of Cognitive Consistency Theories, which posit that our minds check each new belief against all previous beliefs for consistency. Thus, under the new definition, humans are granted omniscience, omnipotence and optimization; the Demon’s closest relative, and construct as-if theories of *optimization under construction*. The most glaring issue of which is that it ignores constraints imposed on human beings, one of which is the lack of omniscience which leads to the conclusion that humans need to search for information. Another issue is that optimization and realism can constrain each other by mutual degradation, that is, optimization is based on what information there is, but, according to what we define or empirically observe to exist also limits the information upon which we base optimization. These first two perspectives set the scene for the most centrally important one. The third perspective is concretely defined through the basic rationale of the Cognitive Illusions Program (Kahneman & Tversky, 1996, and Gilovich, Griffin & Kahneman, 2002), dealing with heuristics and biases. This is to say that humans are blamed for not reaching the ideal of the first two Demons and have *irrational cognitive illusions*. A secondary goal in this perspective is to demonstrate errors conducted in judgment, i.e. exploring systematic deviations from rationality. This view does not question the norms themselves, but rather, retains the norms of the first two Demons and interprets deviations from those norms as cognitive illusions. For example, Tversky and Kahneman (1983) reported that people’s reasoning violated the conjunction rule[5], but they nevertheless retained logic as the norm for rational judgment (Gigerenzer, 2008). It is posited that it is not incorrect to characterise certain behaviours as deviations from logic, but we need to rethink if we want to judge behaviour according to that norm at all. According to Gigerenzer the laws of logic and probability are neither necessary nor sufficient for rational behaviour in the real world and mere verbal labels for heuristics can be posited post hoc to explain any failure (or success) of rational thinking. These three perspectives have obvious issues in their assumptions about human rationality. For one, are content blind norms reasonable? As in, is pure logic a reasonable norm?

Gigerenzer begins this line of reasoning with, in his words, “a most elementary point” (2008, p. 12), English terms such as “if...then” are not identical to logical terms such as the material conditional “-->”. To exemplify this, we take into account Trivers’ (1971) theory of reciprocal altruism; each human possess altruistic and cheating tendencies. Therefore, one goal in a social contract is to search for information that would reveal if you have been cheated by the other party (Cosmides, 1989). The perspective here is essential: You are trying to find out whether you were cheated on by the other person, not if you cheated that other

[5] A law of logic stating that two events can never be more likely than one of those events in isolation.

person. To exemplify that logic is without perspective and not a reasonable norm, the classic four card task (Wason, 1966) residing on truth-table logic will be used. The classic experiment included letters and numbers, where four cards are placed in front of the participant and is given an if-then statement such as, “If there is a vowel on one side then there must be an even number on the other”. Participants see in front of them four cards with an odd number, an even number, a vowel and a consonant, and are asked to choose the appropriate two cards to test the if-then statement. It follows from a truth-table that Modus Ponens, if P then Q, is one logical truth, so the card with a vowel needs to be turned over. The second logical truth is called Modus Tollens, if -Q then -P, resulting in that the “not-even-number” card, i.e. the card with an odd number, must be turned over. Very many get this wrong however, and brain-limitation is blamed according to either of the three rationality-perspectives mentioned. Trivers’ model was introduced to this task, yielding the if-then statement “If a previous employee gets a pension from the firm, then that person must have worked for the firm for at least 10 years.”. The four cards read, “got a pension”, “worked for 10 years”, “no pension” and “worked for 8 years”. Perspective and context, as mentioned earlier, is crucial. When participants were told they were an *employee*, they turned up “worked for 10 years” and “no pension”. When told they were an *employer*, they turned up “got a pension” and “worked for 8 years”. The latter situation renders choices of participants consistent with both Trivers’ model of cheater detection *and* the laws of the truth table. The former situation however, is not consistent with truth-table logic, but is explained by Trivers’ social contract theory. Gigerenzer (2008) argues that this is essentially a frame-of-reference problem and it is unfair to set up (albeit, perhaps, unintentionally) an experiment in this way in order to confirm a hypothesis. Also, another central issue is the lack of available alternative explanations, which ties in the earlier point in presupposing too strongly a framework, theory-ladenness, and explaining any results thereafter, i.e. non-falsifiability coupled with the empiricist fallacy.

In contrast, it is important to note that logic *can* be appropriate as criteria, but its domain is restricted (Gigerenzer, 2008). Truth-table logic experiments have not explained human enterprise, but rather, explored the limits of logic as criteria. The probability/numerical-discrepancy can further demonstrate this idea in the Linda-example; “Linda is 31 years old, single, outspoken, and very bright. She majored in philosophy. As a student she was deeply concerned with issues of discrimination and social justice and also participated in anti-nuclear demonstrations. Which of the following two alternatives are more probable? Linda is a bank teller, or, Linda is a bank teller and is active in the feminist movement? This is where the conjunction fallacy, previously mentioned, comes into play. 85% of undergraduates chose the second alternative (Tversky & Kahneman, 1986). This was considered to be a very stable finding of irrationality, until the question was posed in a slightly different fashion; “There are 100 people that fit the description above (Linda’s), *how many* are, A) Bank tellers and B) Bank tellers and active feminists.” (Hertwig & Gigerenzer, 1999). This change was sufficient to completely eradicate the previous, ostensible, irrational results. These examples demonstrate that the norm leads to a misinterpretation of intelligent semantic and pragmatic inferences as if they were mental blunders. Even a child has a more differentiated understanding of language than logic provides. Children rely on conversational norms, implicit inferences and other intelligent, social, aspects (Fillenbaum, 1977 and Sweetser, 1990). In essence, Gigerenzer (2008) exemplifies that the question is framed in an abstract sense compared to how humans are used to rationalise, also giving natural frequencies instead of abstract percentages improve judgments (for another in-depth example, see Elmore & Gigerenzer, 2005). It is important to note that an internalist view limits the chances to understand this discrepancy.

Thus, the heuristics and biases program has attacked the optimizing Demon, but only on a *descriptive* level, using content-blind norms as a metric to evaluate human irrationality (Gigerenzer, 2008). The conclusion is that we are mostly or sometimes irrational, committing to systematic errors of reasoning. This is likened, by Gigerenzer, to “black-box” behaviourism; we are basically rational beings and the nature of our rationality can be understood through fictions of omniscience, omnipotence and optimisation. The most important point of which is that truth-table logic has had little relevance for Homo Sapiens who had to adapt to a social and physical world, not to systems with artificial syntax, which is what the laws of logic are. It is therefore an issue that logic and probability theories as content blind norms for good reasoning is widespread in contemporary experimental psychology (Gigerenzer, 2008). It can be likened to a proneness to Type III errors; finding the right answer to the wrong question. Inappropriate norms are just not a simple normative problem. Those norms suggest confusing questions, to which, the answers can generate even more confusion of, rather than insight to, human rationality. It is the answer “42” to the question “What is the meaning of life, the universe and everything?” (Adams, 1972). Despite all these falsities however, Wason and Johnson-Laird (1972) interpreted cognitive illusions and their empirical support as a refutation of, amongst others’, Piaget’s theory of operational thinking. The conclusion was that truth-table logic is normative, even after they had criticised it as descriptively false. The Wason task and the Linda example demonstrate that logic is *not* central to rationalisation about such problems and it is therefore inappropriate as criteria to judge human rationality on. This line of reasoning is not new; previously and contemporarily to Wason and Johnson-Laird, Wundt (1973, originally 1912) concluded that logical norms have little to do with thought processes and attempts to apply them in order to illuminate psychological processes are, and have been, fruitless.

Extended Mind Theory

Extended Mind Theory (see Clark & Chalmers, 1998) is another branch of philosophy not quite on terms with representationalism. A representationalist, or internalist, explains the cognitive system of an agent's activity in terms of representations. This invites an anti-extended mind claim, in that it is the represented environment and not the environment itself, that is a part of the cognitive system (Chemero, 2007). This division is referred to by Adams and Aizawa (2008) as the coupling-constitution fallacy: If a wide computational system is coupled to the environment, it does *not* imply that the environment is partly constitutive of the system. Chemero argues that when the system in question is a nonlinearly coupled agent-environment system, the fallacy does not come into play. That is to say that, if the brain does not attempt to represent the environment in a one to one relationship, the fallacy does not apply. This is however what representationalist theory attempts and the consequence is that when there is a cognitive system representing the environment, one could carve off the system from the environment and "[claim] that it is the environment-as-represented that drives the non-extended cognitive system." (Chemero, 2009, p. 32). Kihlstrom, Beer and Klein (2003) however, argue that the explanations we are trying to achieve in psychology is of what the agent does and might do, not of how it represents the world. That representations are essential for the explanatory model in cognitive psychology solely adds burden of proof to the backs of cognitivists, something that is usually not discussed, but assumed, for the experiments to have any (ostensible) value. A metaphysical claim is that there is nothing in the cognitive system called representations, and concerns in more abstract terms what any region of the world is like, regardless of how it is best explained by science. It is a philosophical claim, and we will have to wait to see how much of cognition can be explained without it. Challenging traditional cognitive psychology is an uphill battle against tradition, norm, unfair criteria, Hegelian arguments, the Empiricist Fallacy, theory-ladenness and non-falsifiability. However, on a theoretical basis it has, thus far, little to stand on.

The Utility of Neuropsychology

The contrary arguments so far proposed, has had little impact on the, still, prevailing cognitive psychological discipline. A reason for this, apart from the already mentioned resistance to norm and inability to criticise philosophical fundamentals, is the ostensible support received from neuro-imaging. Before criticising this field, it should be mentioned that neuropsychologists are more often than not aware of all these issues and are working hard to try and counteract them -it is not with the neuroscientists that blame is placed. There are even workshops for neuroscientists in which they go through assumptions at all stages of analysis, one of which is the "Skeptical Neuroimaging Analysis Workshop". An example of a conclusion therefrom is to include information about heartbeat when mapping white-matter pathways in the brain, otherwise heartbeat distorts measurement (Cassidy, 2013). Instead, the issues lie with cognitivists who seem to lack understanding for the fundamental problems with imaging and draw unwarranted conclusions and generalisations and can hardly be seen as a resource in support of traditional cognition at all.

Specifically, careful interpretation of results is necessary for, at least, four specific reasons. What we see in neuroimaging studies is a difference between performing no task and, for example, a list learning task. First of all, it is not a natural environment for humans to lie frozen in an enclosed area fixating on a screen, but more so to a general point; can we ultimately say that performing no task is a valid baseline to compare with performing a task? The assumption is that it is, but again, it only comes about because of the restrictions on methodology because of the practical restraints in testing participants. What other baseline is possible? A second issue is that the difference in activation between the two conditions, depending on particular method, shows a maximum of 5% *difference* in activation. The remaining 95% of the activation is at the same levels under both conditions (Pfeifer and Bongard, 2007). What are those 95%? Contemporary cognitivists tend to ignore them and usually only point to the difference (for example Ochsner & Gross, 2008, or see Logotheitis, 2008, for a discussion on fMRI-techniques), which is clearly all too simplistic. A third issue is brought to our attention through Naghavi and Nyberg (2005), whom caution against too much enthusiasm by stating that "functional neuroimaging techniques can at best specify the *coincidence* of regional brain activations with specific cognitive demands. These methods cannot determine which brain regions are *essential* for a specific cognitive process." (Pfeifer and Bongard, 2007, p. 321). It is important that we do not let unwarranted assumptions and generalisations taint the neuropsychological field, turning it into a modern version of phrenology where different brain parts do different things in isolation. A fourth important aspect is the assumption that the images show "thoughts" or other vague definitions of cognition. What we in fact see, taking fMRI as an example, is a first inference between 'more thoughts' and 'more activation', a second inference from 'amount of activation' to 'amount of blood flow', and a third inference from blood flow to an averaged out numeric value between spatial areas, participants and timeframes. There are thus three steps of inferential logic which makes it vulnerable to both a priori and ad hoc assumptions of what it is we are actually looking at when we are presented with these images. There is thus little support gained, at the present moment in time, from the maturing field of neuropsychology. We simply do not yet have enough knowledge or specific (or enough controlled) techniques to confidently state what the brain is *doing*. What are we actually looking at?

Ruthless Reduction

Reduction refers to the process of defining concepts on one level of science to a higher, more encompassing one, in terms belonging to that higher level. For example Churchland (2002), argues that cognitive psychology can be reduced to neuropsychology. This is done on the basis of cognition relying on a "higher" domain for support, but neuropsychology has, just previously, been shown not to lend itself in support of cognitive psychology. It is still, however, posited that the neurosciences will account for the generalisations, laws and facts of cognitive science. A point of argument that speaks against Churchland's (2002) is provided by Bickle (2003), whom proposes a related but more extreme stance, ruthless reductionism. Here, cognitive science can be reduced to a *molecular* level, rather than cognitive neuroscience. His line of argument is that it is irrelevant to exemplify, in philosophy, to that of aliens or angels, essentially, "other-than-brain-stuff". Bickle argues that LTP (in neurobiology involved in the internalist term, long term memory) is realised on earth in exactly *one* way and it is not multiply realised. Ruthless reductionism works from the understanding that other abilities that interests cognitive scientists will be accounted for as long term memory has been. That is, in terms of molecular and genetic processes that do not vary in their realisation in living things on earth. It thus introduces further mistrust in representational and computational assumptions of both cognitive science and the inferences drawn from neuroscience, when argued from a ruthless reductionist standpoint. It should however be mentioned that this concerns the *current* state of neuroscience, an area that will develop over time if it does not wish to attach too much of its theory to representationalism, and fall alongside it. Chemero's (2007) standpoint is that of cautious approval of ruthless reductionism, because it cuts many kinds of a priori Hegelian arguments down. That is, ruthless reductionism refutes statements such as "a theory with a specific assumption cannot account for a specific subject matter". Ruthless reductionism is still on par with other types of reduction, but simply takes it one step further, down to genetics and biochemistry. It thus rules out many unnecessary and would-be-problematic connections between cognition and neurophysiology.

A Last Outpost

Although representations are unobservable entities with only assumptions to rely on, yet are essential for contemporary cognitive psychology, and thus *needs* to physically exist, the only thing left to deal with in representationalism is that of Entity Realism. This is the proposition that you can still be justified in assuming a realist standpoint for *theoretical entities* (and representations fits this bill), if one has pragmatic use for them as tools in experimental investigation of other entities (Chemero, 2007). A direct issue with this assertion is demonstrated by Ashby (1947, 1962), exemplified by a dog that is afraid of cars because it was hit by one in the past. It needs to be established that unobservable theoretical entities need not exist just because they conveniently lend themselves as tools; we are likely to see the dog as 'having' a memory and this in turn suggests that we could look for the dog's memory as if it existed inside the dog. But, all that we are actually positing is that a specific behaviour can be *explained* by a previous state, not what exists inside the dog. As in the case of asking participants to recall a list of words, the explanation given for their current behaviour is by reference to a previous behaviour, but, what went on in participants have not actually been observed, the word 'memory' is just used to fill this gap (Barrett, 2011). In other words, the issue with this proposition is that, because representations are *necessary* for the internalist account, yet have not been established empirically to actually exist, the assumption *does not really explain anything*. It is merely stating that, this is *one possible* process that *may* occur because it *would* fit the criteria for linking one behaviour to another. There is doubt that cognitive scientists would resort to this however, since the power of the concept is drastically reduced, and in all right. This line of reasoning is reified by Gigerenzer (2008), whom makes the point that concepts like representations are silent about the actual process; we do not explain anything just by defining a hypothetical process in words.

A Final Remark

The conclusion is that many of the kinds of experiments used as examples herein beg the question. The methodological design assumes the existence of a concept that the experiment is trying to discover; then it is not too surprising that a particular kind of concept is found either (Barrett, 2011). It follows from this that we have not actually gotten closer to explaining human enterprise. All we have done is named unobservable, hypothetical processes, leading us down a garden path away from the core subject of psychology. We want to understand why humans behave the way they do, we want to understand what the brain does. Representationalism does not provide these answers and “...if we cannot do any better than this, we should stop using the word...” (Gibson, 1986, p. 254).

Introduction to Ecological Psychology and radical Embodied Cognitive Science

Even within Embodied Cognition, there are alternatives of how exactly to pin down the Embodied Cognitive approach. Some suggest that we should stick with a dualistic perspective, not denying representations but that we may just not rely on them always for acting in the world (individual papers in Semin & Smith, 2008). Another school within the Embodied Cognitive approach argues for the perspective that representations do not exist at all, or, they are useless either way and we should abandon that practice altogether (Gibson, 1986, Chemero, 2007, and Barrett, 2011). Even in agreement with the latter, there are still differences on the conceptual definitions within the perspective. It is also a rare occasion to find epistemological and ontological definitions in the literature. Therefore an attempt is made to philosophically define and restrict the ontological basis upon which radical[6] Embodied Cognitive Science (henceforth; rECS, coined by Chemero, 2007) is built. Its main division is that of the mentioned full rejection of representations, something that Gibson with his full explication and definition of ecological psychology would endorse. It should thus also be mentioned that the fundamental basis is credited to Gibson, considered as the grounding father of the ecological perspective (although there had been many influences before, no one had defined the full basis on which they relied). Therefore, Gibson’s (1986)[7] grounding basis will be presented and followed up by contemporary changes and extensions to the research program, then continue on to practical research. Finally, the discrepancy of depictions and what they inform/afford an agent is discussed in light of computer-screen research, leading on to the study at hand.

Perception is a most central aspect of this theory, and will be dealt with accordingly, but first the environment must be described, since what there is to be perceived has to first be defined before we can even talk about perceiving it. Also, the information that is available for perception in an illuminated medium must be described, and lastly, the process of perception will be explicated. It is not seen as sensory inputs, but the extracting of invariants from the stimulus flux. “The old idea that sensory inputs are converted into perceptions by operations of the mind is rejected.” (p. 2). It is also the case that if the physiological images of the two retinas were not combined or unified, we should see two objects instead of one. Ecological

[6] A first note here is that “radical” is not given a capital letter to indicate that it is not radical in and of itself, but rather, that it is a departure from the overarching discipline of Embodied Cognition.
[7] Page-references in this chapter refer to this book, unless otherwise stated.

optics does not make these assumptions, rejecting also the very idea of a physiological image transmitted to the brain. It supposes that two eyes have no more difficulty in perceiving one object than two hands do in feeling one, or two ears do in hearing one event (p. 213).

Traditional cognitive psychology determines that sensation occurs first, perception next and lastly knowledge, a progression from lower to higher mental processes. One process is the filtering of sensory inputs, and another is the organising of sensory inputs -the grouping of elements into a spatial pattern. Gibson argues that some theorists propose mental operations and others argue for semi-logical processes or problem-solving, and yet others are in favour of a process analogous to the decoding of signals. All theorists however seem to agree that past experience is brought to bear on the sensory inputs, which means that memories are somehow applied to them. Apart from filtering and organising, the processes suggested are cognitive (p. 251). The issues of representationalism have been covered however and will now be left behind. The proposition is to replace these ideas with Gibson's Ecological Psychology and Chemero's radical Embodied Cognitive Science.

Gibson's Ecological Psychology

Environment will be used in a very specific way, it is the surroundings of the organisms that perceive and act. An environment automatically implies an animal, and vice versa, a point later returned to. Gibson speaks of the environment as existent in an *ecological world* in contrast to the *physical world*. They are separated due to perspective, that is, the physical world contains the atomical level, atoms on a 10^-9 meter scale, and the astronomical level, on the size range of 10^9 meters and beyond. These are not environments because the environment, in terms of length, contains animals with a range from fractions of a millimeter to multiple meters. The mass of animals are measured within the range of kilograms and milligrams, and not here either at the extremes of the scale. Also, there are smaller units, like leaves, that are embedded in larger units, like trees, by what Gibson (1986) termed *nesting*. Things are components of other things and there are forms within forms both up and down the scale of size but there are no atomic units of the *environment*, instead, there are subordinate and superordinate units. The literal basis of the environment is the ground, perpendicular to gravity, and the components of the ground tend to be regular, evenly spaced, and if they are scattered they are usually evenly scattered. For example, components of the ground do not get smaller as one travels north (p. 10). When it comes to time, the changes that we usually perceive are neither extremely slow, like the erosion of mountains, nor extremely fast, like the movement of electrons. When it comes to apprehending time, we do not perceive time per say, but processes, changes and sequences: Human awareness of clocktime is another matter, because the flow of abstract empty time has no reality for an animal (but is useful, for example, in physics). This would be why we find one sequence of time as "fast" and another as "slow". Generally speaking, it may seem a bit strange at this point introducing these types of limits, however it should suffice to say that this comprises what and where animals *live, do* and *perceive* on a daily basis. We do this in the environment, and neither on an astronomical level, nor on an atomical level.

The shape of the environment is termed as *layout* and is both permanent and changing in certain respects. When permanence is considered, it is a relative statement because it depends on the time-frame for persistence and almost nothing is forever permanent. "So it is better to speak of *persistence under change*. "Permanent objects" just persist a very long time." (p. 13). Solid substances are not readily changed in shape and when referring to the permanent layout, it is meant mainly as the solid substances. A liquid substance takes whatever shape of its solid container, like the streams and oceans, are thus shaped by solids. The gaseous matter, the air, is not shaped at all, it is a *medium*. When a solid substance with a constant shape melts, like an ice cube, we say that the object has ceased to exist. "This way of speaking is ecological, not physical, for there is physical conservation of matter and mass despite the change from solid to liquid. The same would be true if a shaped object disintegrated, changing from solid to granular. The object does not persist but the matter does." (p. 13). In an ecological perspective, this would be called non-persistence, whereas in physics it would be called a mere change of state. Both are correct, but the proposition is that the ecological perspective is more relevant to the behaviour of animals. It should be mentioned however that physics convinces us that nothing really has gone out of existence, but this is not true. Even if matter cannot disappear, a resistant light-reflecting surface can - and that is what counts for our perception of such a thing.

The surface is where most of the action is, it is where light is reflected or absorbed, what touches the animal, where chemical reaction mostly takes place, where vaporisation or diffusion of substances into the medium occurs and it is where vibrations of substances are transmitted into the medium. Gibson suggests the following laws of surfaces;

- All persisting substances have surfaces, and all surfaces have a layout.
- Any surface has resistance to deformation, depending on the viscosity of the substance.
- Any surface has resistance to disintegration, depending on the cohesion of the substance.

- Any surface has a characteristic texture, depending on the composition of the substance. It generally has both a layout texture and a pigment texture.
- Any surface has a characteristic shape, or large scale layout.
- A surface may be strongly or weakly illuminated, in light or in shade.
- An illuminated surface may absorb either much or little of the illumination falling on it.
- A surface has a characteristic reflectance, depending on the substance.
- A surface has a characteristic distribution of the reflectance ratios of the different wavelengths of the light, depending on the substance. This property [is its] colour, in the sense that different distributions constitute different colours. (p. 23-24)

The most important aspect of the definitions of surfaces, is that the fundamental way in which surfaces are laid out, have an intrinsic meaning for behaviour, unlike the abstract, formal, intellectual concepts of mathematical space (p. 44). This is to say that the world of physical reality does not consist of meaningful things, but the world of ecological reality does. If what we perceived were in terms of physics and mathematics, then meaning would have to be added on to them somehow. But if what we perceive are the entities of ecological reality, then their meanings can be *discovered* (p. 33). This point will be further elaborated upon, as it connects with the proposition of *direct perception* (that we perceive the world for what it really is).

In the medium there are no sharp transitions, that is to say that there are no boundaries between one volume and another, no surfaces. This homogeneity is crucial because it permits light and sound waves to travel outwards from a source in spherical wavefronts. It is also what makes chemicals able to emanate from a source that is foreign to the medium itself, enabling it to be smelled (p. 18). So, the characteristic of the environmental medium is that it affords respiration and locomotion; it can be filled with illumination to permit vision; it allows detection of vibrations and emanation; it is homogenous and it has an absolute axis of reference, up and down. Gravity pulls downward, not upward, radiant light comes from above, not below and the medium lends itself to respiration. These *affordances* are invariant, they have been constant throughout evolution (p. 19). A last note specifically concerning mediums, for aquatic animals, water is a medium, not a substance. It doesn’t invalidate the distinction but only makes it dependent on the kind of animal considered. For humans, water belongs to the category of substances, not mediums. Animal locomotion is not usually aimless, but is guided or controlled; because of illumination, the animal can see things; because of sound, it can hear things and; because of diffusion, it can smell things. By detecting this information the animal guides and controls locomotion. Describing the environment in terms of medium, substances and surfaces is thus superior to the traditional cognitive perspective because it is an appropriate classification when studying perception and behaviour of animals and humans.

Radiation (from the sun, for example) becomes illumination by reverberating between the earth and the sky and between surfaces that face one another. The medium in the environment is a region in which light is not only transmitted, but also *reverberates*. That is, light bounces back and forth between surfaces at very high speed and reaches a kind of steady state. For this to exist, light has to be continually replenished from a source of illumination, because, some of the light is absorbed by substances in the environment. *Ambient light* comes to every possible point of observation and this type of omnidirectional flux of light could not exist in empty space, but only in an environment of reflecting surfaces. The only way we see illumination, is by what is illuminated, the surface upon which the beam falls. Building on this, an *ambient optic array* is defined as ambient light *with structure*. According to Gibson (p. 53), fog is a medium, and in a completely fog filled room there is no structure, but there can be ambient light. There is thus also a distinction between potential stimulation and actual stimulation (the presence of photoreceptors)[8].

An *essential structure* consists of what is invariant, even when the observation point is moving (that is, locomotion). In contrast, *perspective structure* changes with every displacement of the point of observation and it follows from this that the shorter the displacement, the smaller the change. To clarify, when ambient light at a point of observation is structured, it is an ambient optic array. The structure of an ambient array can be described in terms of visual solid angles with a common apex at the point of observation. They are angles of interrupt and determined by the persisting environment, no two such angles are identical. The solid angles of an array change as the perspective structure moves, underlying the latter however, is an invariant structure that does *not* change. When describing observation points, it is useful to speak of *exterospecific* and *propriospecific*. The former specifies a possible observation point and the latter an occupied observation point. When a point is occupied, there is also optical information to specify the observer herself and this information *cannot* be shared by other observers. The reason is that the body of the animal which is observing temporarily conceals some part of the environment that is unique to that animal (p. 111). The optical information to specify the self, includes the head, body, arms and

[8] Sensory receptors are stimulated, but a sensory organ is activated.

hands, and *always accompanies* the optical information that specifies the environment. An important point of this is that the two sources of information coexist and could not exist without the other. This has important implications for the idea of separating a perspective into subjective and objective. Gibson argues that these are actually only poles of attention and the dualism of observer and environment is unnecessary. The information for the perception of “here” is the same kind of information for the perception of “there”, and a continuous layout of surfaces extends from one to the other. The gradients of increasing density of texture and increased distance all the way from the observer’s nose out to the horizon are actually variables between two limits. This implies the complementarity of proprioception and exteroception in perception. That is to say, self-perception and environmental perception go together. An example is appropriate here: Infants practice looking at their hands for hours, as well as they should, for the disturbances of optical structure that specify apprehension have to be distinguished. All manipulations, from the most crude like grasping, to the most acute act of brain surgery, must be guided by those disturbances if they are to be successful. Furthermore, the visual solid angle of the hand cannot be reduced below a certain minimum, but it can for a ball by throwing it. The range between magnification and minification connect the extremes of “here” and “out there”, the body and the world, and exemplify another amelioration of the divide between subjective and objective.

Another illuminating example of what makes egoreception[9] so useful is that of simultaneous sensory perception. It is easy to conceive that the physical contact between foot and surface is specified by mechanical impressions, and that, by touch, there would be no use for an optical specification as well. However, we are used to getting both optical and cutaneous information about this activity and so an invisible glass floor high above the real floor supplies mechanical support but not optical support. This is the reason why human infants and other terrestrial animals show distress, flinching and behaving as if falling when placed in such a situation. Thus, locomotion with respect to the earth, active or passive, is registered by vision but supplementary information about the movement is picked up by the haptic system (Gibson, 1966). When it comes to moving and being still, moving entails a flowing perspective structure whereas being still entails a frozen perspective structure in the ambient array. They contain information about the potential observer and not information about the environment (as the invariants do, but, they imply each other). Also, a flowing perspective structure specifies both movement and, more specifically, a particular instance of

[9] Defined as perceiving parts of oneself, always.

flow specifies the particular path of movement. This is to say that the *course* of the optical flow is specific to the *route* that the path of movement takes through the environment. In conclusion, the flowing perspective structure and the underlying invariant structure are concurrent and exist at the same time even though they specify different things (p. 75).

Affordances

"The affordances of the environment are what it *offers* the animal, what it *provides* or *furnishes*, either for good or ill." (p. 127). It implies complementarity of the animal and the environment. Properties of surfaces, like horizontal, flat, extended and rigid, would be physical properties if they were measured with the scales and standard units used in physics. As an affordance however, they have to be measured relative to the animal. It is important to note that they are not just abstract physical properties, they have unity relative to the posture and behaviour of the animal being considered -so an affordance cannot be measured in physics. Affordances are in a sense objective, real and physical, unlike values and meanings, which are often supposed to be subjective, phenomenal and mental. "But, actually, an affordance is neither an objective nor subjective property; or both if you like. ...An affordance points both ways, to the environment and to the observer. The organism depends on its environment for its life, but the environment does not depend on the organism for its existence." (p. 129). Another aspect to consider here is the importance of being distinct and clear on the ontology of affordances, a philosophical point. "Affordances are of both" and other statements can, wrongly, suggest the dependence of existence on relationships, and it is impossible to wager this proposition in an ontological sense without (perhaps unintentionally) moving towards idealism. This is not an acceptable outcome and will be explained in depth as Chemero (2007) is a proponent of defining affordances in terms of relationships. For now, it is enough to mention that the relationship comes about by that perceiving contains both yourself and environment and an affordance arises only in the enactment of what the environment affords the agent coupled with which movements the morphology of the agent allows. As such, you do not only specify the environment, but at the same time you also specify yourself in that environment. Any given action is then done in concordance with which actions are available in the environment, therefore, an affordance specifies both at the same time.

What we perceive when we look at objects are their affordances and not their qualities although we could discriminate the dimensions of difference if we were required to do so. However, what we normally pay attention to is what the object affords us. An infant, for example, does not begin to first discriminate which qualities an object has and then learn the combination of the qualities that specify the object. "The meaning is observed before the substance and surface, the colour and form, are seen as such. An affordance is an invariant combination of variables and one might guess that it is easier to perceive such an invariant unit than it is to perceive all the variables separately. It is never necessary to distinguish *all* the features of an object and, in fact, it would be impossible to do so. Perception is economical." (p. 134).

Koffka (1935) proposed that one is only attracted to a post-box when one has a letter to post, and not otherwise. Gibson challenges this assertion by stating that affordances do not change as the need of the observer changes. The observer may or may not perceive or attend to the affordance, but the affordance is invariant, it is always there to be perceived. There is however an easier way of explaining why values of things seem to be perceived immediately and directly. This is because affordances are specified in stimulus information; they seem to be perceived directly because they *are* perceived directly (p. 140). Koffka was a gestalt psychologist and objected to the accepted theories of perception which posited that no experiences were direct, except sensations and these mediated all other kinds of experience. "Bare sensations had to be clothed with meaning" (p. 140), that is to say, the traditional view had it that sensations were without meaning, something that had to be added to the sensations (presumably in our brain, or worse, mind), and thus direct perception of meaning was unorthodox at the time Gibson proposed it. Gestalt psychology, however, began to undermine sensation-based theories, but they didn't manage to go beyond them (p. 140). Ecological psychology then takes direct perception to include *meaning*, as opposed to representationalism and gestalt theory.

Perception

It has been proposed that physical metrics does not apply to perception, and there is a need to clarify this proposition. The question is, how can we isolate and control an invariant of optical structure in order to apply it to an observer if we can't quantify it? Firstly, we cannot apply an invariant to an observer, we can only make it available to them. Secondly, we do not have to quantify an invariant but we can give it an exact mathematical description so that other researchers can make it available to *their* observers. "The virtue of the psychophysical experiment is simply that it is disciplined, not that it relates the psychical to the physical by a metric formula." (p. 141). This statement, firstly, is significant in that it further separates other disciplines from psychology, an important feature if psychology is to be defined on its own terms. Secondly, it is worth to point out, again, that an affordance points two ways, to observer and environment and so does the information that specifies it.

But, this does not imply separate realms of consciousness and matter. The awareness of the world and one's complementary relations to the world are not separable.

When it comes to visual perception, Gibson's theory asserts that it does not begin with a two-dimensional form of perception and so there is no special kind of perception called depth perception. The third dimension is not lost in the retinal image since it was never in the environment to begin with. The traditional cognitive theory of depth perception is based on confusion of traditional optics and is perpetuated by the fallacy of the retinal picture (p. 148). When investigating vision or visual attention, it is not uncommon to fixate the head or have participants stare at a single point on a screen. However, if an animal has eyes it will move its head around and move from place to place. The single, frozen field of view only provides impoverished information about the world, and most importantly, the visual system did not evolve for this (p. 2). A discrimination is needed between these different types of vision, something Gibson provides as follows; *snapshot vision* is studied by first requiring the participant to fixate on a point and then temporarily expose a stimuli or pattern of stimuli around this point. *Aperture vision* applies to situations where the exposure is longer and the eye will scan the pattern, fixating on different parts in succession, like looking through a hole in a fence. This is not natural vision, as we are almost always in movement, even when sitting still or lying down. Pictorial stimuli enabled vision to be explored experimentally but makes it seem as if snapshot vision and aperture vision is all there is to discover. "Natural vision *can* be studied experimentally. It is not true that "the laboratory can never be like life." The lab *must* be like life!" (p. 3). Metzger (1930) was first to investigate whether tridimensional space was based on bidimensional sensations to which the third dimension was added, or if it was based on surface perception. He concluded that he saw something in three dimensions, that is, he was perceiving "space". This was to Gibson the reason that the third dimension and space were misconceived concepts. A perfectly flat surface in front of the eyes is still a layout, a wall, and this is all that "seeing in two dimensions" can possibly mean (p. 152). Gibson and Waddell (1952) had participants cover each eye with a fitted cap of strongly diffusing translucent material. This is a different way to Metzger to produce the same effect, to get a homogenous field to fill the visual field. The experience of wearing this goggle-type aperture is that of blindness, not to light, because the photoreceptors are still stimulated, but to the environment because the ocular system is inactivated. Gibson and Waddell (1952) were aware of animals reared in complete darkness, the consequence of which was that those animals were blind by certain criteria. With the translucent eye-caps however, animals were deprived of optical structure but not stimulation and were found to also be partly blind when the caps were removed. In a simple sense, they could not *use* their eyes properly. The animals reared in the dark had had anatomical degeneration of photoreceptors but this was not the case with the translucent eye-caps. Instead, exploratory adjustments of the visual system had not developed normally (Gibson, 1969). In concordance with this, Gibson and Walk (1960) created a glass floor that afforded support in two different ways. In one condition a paper was stuck immediately under the glass and in the other the paper was placed far beneath it. Animals and babies were participants in this experiment and crawled normally in the first condition but in the second they displayed discomfort, froze, and some animals even adopted the posture they would have when falling. The conclusion to this experiment is that certain animals require optical information for support together with inertial and tactual information in order to walk normally. Optical information that is contradictory to haptic information perception is, as has been mentioned, inseparable between oneself and environment. One's body in relation to the ground is what gets attention. None of the commonly accepted theories of space perception bring out this fact (Gibson, 1986, and Chemero, 2007). It is thus an important point that Ecological Psychology can explain empirical observations that traditional cognition cannot, a pivotal aspect of replacing current theory.

Visual perception and past/present/future. The old approach to perception took the central problem to be how one could see into the distance and never asked how one could see into the past and the future. These were not problems of perception because the past was remembered and the future was imagined. Perception only come into play when we are speaking of the present. But, there is still difficulty in deciding how long the present lasts, or what distinguishes memories from imaginations. It is also an issue to decide when percepts began to be stored, or which got stored and where. Gibson's approach to perception suggests that perception as a general term is timeless and that present-past-future are only relevant to the awareness of self. "The environment seen-at-this-moment does not constitute the environment that is seen. Neither does the environment seen-from-this-point constitute the environment that is seen. The seen-now and the seen-from-here specify the self, not the environment, consider them separately." (p. 196). In a similar manner, to adopt the view of another person is not an advanced achievement of conceptual thought. It only means that, I can perceive surfaces hidden at my point of view but unhidden at yours. This only means that, I can perceive a surface that is behind another, and if so, we can both perceive the same world. An implication of this is to say that to be aware of the environment behind one's head, is to be aware of the *persistence* of the environment.

A curious departure from strict theory may be needed at this point, it takes on the form of public and private knowledge: The human habit of covering the body with clothes, is a matter of hiding some surfaces of the skin and not others (depending on the conventions of culture). To display the usually covered surfaces is improper or immodest "...and the careful manipulation of the occluding edges of clothing with progressive revealing of skin is a form of theatrical art called stripping." (p. 202).

Traditional cognitive theory suggests that successive inputs of a sensory nerve are processed, that series of signals are interpreted, or that the incoming data of sense are operated on by the mind. In short, senses are converted into perceptions, but how does this come about? The process is supposed to be memory. It can be called short term memory or working memory as opposed to long term memory, but the basic assumption is that each image has to be stored in some sense in order for the sequence to be integrated (combined into a unit). Past perceptions cannot combine with the present except as memories and every item of experience has to be carried forward into the present in order to make possible perception in the present. Memory has to accumulate. The error in this reasoning is that perception of the environment is based on a sequence of discrete images. If it instead is based on invariance in a flow of stimulation, the problem of integration does not arise. There is no longer any need to unify or combine different pictures if the scene is *in* the sequence and it is specified by the invariant structure that underlies the samples of the ambient array. The traditional assumption behind perception is that we perceive the world by means of a sequence of stimuli. Looking at a scene, we see it in a succession of glimpses analogous to snapshots, each glimpse corresponding to a pure fixation. These have been vaguely defined with retinal images, but is a false assumption. Visual fixation is not at all comparable to a snapshot, the eye scans over the whole field and the fovea is transposed over the sample of the array. Not even the fixed visual field of a head posture is comparable to a picture in a sequence of pictures, because the field sweeps over the ambient array with progressive gain and loss at its leading and trailing edges (and the ambient structure remains invariant). The century old problem of why the world does not seem to move when the eyes move and why a room does not appear to go around when one looks around, are unnecessary. They arise from the assumption that visual stimuli and sensations are elements of visual perception. Instead, if the visual system is assumed to instead detect its own movements and extracting information about the world from ambient light, the puzzle disappears.

Summary, memory and knowledge. According to Gibson's Ecological Theory, *perceiving* is a registering of certain definite dimensions of invariance in the stimulus flux together with definite parameters of disturbances. The invariants are invariants of structure, and the disturbances are disturbances of structure. The structure, for vision, is that of the ambient optic array. The invariants specify the persistence of the environment and of oneself. The disturbances specify the changes in the environment and of oneself. A perceiver is aware of her existence in a persisting environment and is also aware of her movements relative to the environment, along with the motions of objects and non-rigid surfaces relative to the environment. The term awareness is used to imply a direct pickup of the information, not necessarily to imply consciousness (p. 244-250). When it comes specifically to "memory" and "knowledge", it simply develops as perception develops, extends as an observer travels. This is to say that it gets finer as they learn to scrutinize, gets longer as they apprehend more events, gets fuller as they see more objects and gets richer as they notice more affordances. Knowledge of this sort does not come from anywhere, it is gotten by looking, hearing, feeling, smelling and tasting. Naturally, a child acquires knowledge that comes from parents, teachers, pictures and books but it is a different kind of knowledge (paraphrased, p. 253).

It can seem intuitive to understand the difference between past and present experiences but it is denied when stating that we can experience both change and non-change. The "stream of experience" does not consist of an instantaneous present and a linear past that recedes into the distance; "it is not a "traveling razor's edge" dividing the past from the future" (p. 253). If the present has a specific duration, then it should be possible to find out when perceiving stops and memory begins, but this is not a clear-cut dichotomy. Attempts have been made to talk about the conscious present, specious present or a span of working memory. They all fail on the same simple fact that there is no dividing line between present and past, perceiving and remembering. It is obviously clear that sense impression ceases when the sensory excitation ends, but a perception does not. The proposition is that a memory does not exist after a certain length of time, because a perception does not have an end. Perception goes on. Perhaps one part of the issue is that the dichotomy of present and past comes from language use, and there is no intermediate to explain a continuously ongoing process.

Picking up information from the ambient array makes a clear-cut separation between perception and fantasy, but it closes the ostensible gap between perception and knowledge (p. 258). Extracting and abstracting invariants happens both in perceiving and knowing, they are different in degree but not in kind. Supposing that seeing something is different to knowing something, come from the old doctrine that seeing is having temporary sensations and knowing is having permanent concepts stored in memory. It should by now be clear that perceptual seeing is an awareness of persisting structure. Knowing is thus an extension of perceiving, a child explores the world with all her senses but is also made aware, by others, too. “She is shown things, and told things, and given models and pictures of things, and then instruments and tools and books, and finally rules and shortcuts for finding out more things. ... They transmit to the next generation the tricks of the human trade. ... The extracting and abstracting of invariants that specify the environment are made vastly easier with these aids to comprehension. But they are not in themselves knowledge, as we are tempted to think. All they can do is facilitate knowing by the young.” (p. 258). Apprehensions are all cases of picking up information from a stimulus flux, but the information itself is largely independent of the stimulus flux.

Dynamic Systems Theory

Removing the fundamental basis of representations and computation presents a challenge to replace it with something else. Dynamicism, or Dynamic Systems Theory, was introduced by van Gelder in his paper *What might cognition be if not computation* (1995). He reasons that pure systems of embodied cognition do not even make sense to put in computational or representational systems. The important point is that, if they would, they would still only account for one point in time, rather than what is necessarily inherent in the system -change over time. Time holds no information about the actual system, it is useless in isolation. It could however be argued that it holds some utility when compared to other values of itself and the rest of the system. But, like pictures on a screen, this paints an insufficient image of what there is to perceive. Everything always happen over time, and details of timing (durations, rates, rhythms and so on) are critical to systems that operate in a body and environment. Computational models are inherently limited in this respect, but a dynamical account of cognition promises to minimize difficulties in understanding how cognitive systems are real biological systems in constant, intimate dependence on, or interaction with, their surrounds. The Cartesian picture[10], the inheritance of Western civilisation (van Gelder, 1995, and Chemero, 2007) lends itself readily to the computational conception of mind, and seriously misconceives its place in nature. The Cartesian tradition is mistaken in assuming that mind is an inner kind of entity. van Gelder argues that ontologically, mind is much more a matter of what we do within environmental and social possibilities. Reconceiving the human agent as essentially embedded in a changing world and that thinking about the world is secondary to, and dependent upon, such embeddedness. As argued in the previous chapter,

[10] While it involves many more arguments, the central one here is that there exist something internal to us called mind that interprets, adds meaning and so on to external stimuli.

a fundamental mistake is to suppose that practical function is accounted for by theory. This is to say that knowledge *how* is explained in terms of knowledge *that*. “Cognition, the inner causal underpinning of mind, is not to be explained in terms of the basic entities of the Cartesian concept of mind.” (van Gelder, 1995, p. 381). Also, as have been argued in this chapter, a post-Cartesian agent copes with the world without necessarily representing it. The example of this that van Gelder proposes is the Watt governor, a mechanical machine that increases, decreases or maintains speed of a steam-engine. Before its invention, the issue was of stabilizing the change in speed of a steam engine, current technology made it a bumpy ride. The technical difficulties to create this machine are beyond this paper, it suffices to say that what was needed was a measurement of the speed of the flywheel, compare the actual speed against desired speed, measure the current steam pressure, calculate the desired alteration in steam pressure, calculate the necessary throttle valve adjustment and then make the throttle valve adjustment. In real time. Continuously. Watt, however, adapted a solution from existing windmill technology; consisting of a vertical spindle geared into the main flywheel so that it rotated at a speed directly dependent on the flywheel itself. Attached by hinges to the spindle were two arms and on the end of each, a metal ball. When the spindle turned, centrifugal force drove the balls outward (and thus upward). The arm motion was linked directly to the throttle valve and resulted in that the speed of the main wheel increased, the arms raised, closing the valve and restricting the flow of steam -the opposite for increasing flow of steam. A remarkable feat of engineering. The above explanation of the Watt governor does not require representations to be explained (although perhaps a visual aid would). Just because something is explainable in other terms does not deny their existence, but, there is nothing over and above that representations can bring to the table. Another important aspect is that the Watt governor does not, and need not, contain any calculations. Additionally, it can only be transcribed to computation through cumbersome mathematical gymnastics. This is not the point however, the point is that even then, it would only account for one point in time, and even if accounting for several points in time it does us no good to just *describe* what it does on a point, or several, in time. What is distinguishing for it, is that it changes in real time, depending on quite complex activities and as there is a change in one part, there is an *immediate* change on the opposite side. There is no calculation, computation or representation necessary neither for the inherent mechanisms nor for explaining its “behaviour”.

van Gelder argues in concurrence with Chemero (2007) that, for example, decision making theories make the same general mistakes. A dominant approach to decision-making stems from expected utility theory and statistical decision theory (originally developed by von Neumann and Morgenstern, 1944). The idea is that we make decisions based on selecting the option regarded as yielding the highest expected utility. This is calculated mathematically, and provides a useful description of optimal reasoning strategies. But it is ultimately flawed because demonstrated human behaviour deviates from predictions of the theory. They all suffer from not incorporating any account of underlying motivations that give rise to the utility an object or outcome holds at a given time. They also conceive of utilities themselves as static values and does not give a good account of how and why they could change over time and why preferences are often inconsistent and inconstant. A last point by van Gelder is that they do not offer any serious account of the deliberation process and they have nothing to say about the relationships that have been uncovered between time spent deliberating and the choices eventually made (van Gelder, 1995). They all fail to account for time. *The* inherent issue in contemporary cognitive theory.

rECS and Modifications Thereof

We turn then to the contemporary and extended changes to theory, and already here a departure is made from Chemero's (2007) rECS definition of affordances as relationships. However, because ontology and epistemology have not been separated distinctly, it is difficult to know in which sense previous literature uses the word relationship. Therefore, we turn to ontology next, to clarify further the philosophical underpinning of rECS, specifically those of affordances and later, their epistemological underpinning.

Ontology of affordances. Ontology deals with questions concerning what entities exist or can be said to exist. The dividing up of affordance in ontology and epistemology is rarely explicitly and clearly mentioned in the literature but has central importance in the definition of the most important concept in rECS. One aspect of the ontological basis is that the theory needs to follow realist assumptions. Realist here is defined coarsely as *the world exists independent of the mind*, or, *the world exists independent of us perceiving it*. The reason this is important is that materialistic monism, through which science attempts to understand and explore, is a derivative of realism. For psychology not to be tainted by magical thinking and dualistic notions on the turn towards rECS, we simply must define 'what exists' by realism, or perhaps rather, materialistic monism. There is therefore an issue with defining affordances in terms of relationships and how easily an ontological (mis)definition of affordances can lead us away from realism and instead end up in the unsatisfactory claims of idealism.

The first thing to establish is that an ontological definition of affordances cannot include, in full or in part, a relationship between two entities, in contrast to Chemero (2007). Relationships imply a mono-dependence or co-dependence on one another, and, including ontology, this implies that dependence on one another defines what exists and not. The cases look as such:

The case of mono-dependence;

1. If either entity is dependent on the other, and
2. dependence is required for existence,
3. then, there will be situations where either will not exist.

The case of co-dependence;

1. If both entities are dependent on each other, and
2. dependence is required for existence,
3. then, there will be situations where neither will exist.

Therefore, if affordances are, in full or in part, defined ontologically as a relationship, then affordances will align itself with idealism, since we will have situations where one or both entities do not exist. There are however restrictions because of the physical properties inherent in the system; physical properties hierarchically define the way in which we can interact with other agents, objects and the environment. For example, the human body, or more specifically, the leg, due to its physical properties (the knee), cannot bend its leg backwards. Here, the physical properties constrain the actions able to be taken by the human body in its interaction with other agents, objects and the environment. The same is true of objects, their physical properties constrain which affordances are available to different agents. As an example, water, due to its molecules' loose bonds to each other creates a surface tension that is not walk-on-able for a human, but is so for a water strider (insect) or a fishing spider. With water as an example, it nicely brings in the environmental constraints: While surface tension lends itself to be walk-on-able by small insects and spiders, and not by a human, one could draw the simplistic conclusion that weight is the common denominator, but, bazilisk lizards and water birds can also walk on water by overcoming certain limitations. Weight is inherent in morphology but only when coupled with the environmental constraint of gravity does it have consequences for the animal. Gravity forces the lizard downward, and at stand still in water, surface tension cannot carry it. However, by running, its downward stroke pushes water away from its leg, this creates a pocket of air around its foot that it uses to push off again. The lizard must move its legs fast enough or the pocket of air will break surface tension and disappear from under the lizards foot (Konkel, 2010). This, in fact, exemplifies the constraints of agent (the lizard's body weight and the shape of its legs and feet), objects (water molecules forming surface tension) *and* environment (gravity) and the way all three necessarily form relationships, and interact, with each other to allow or deny affordances and overcome limitations. This is not to be confused with ontology however and allowing/denying here refers not to that the affordances of water and the lizard does not exist if the lizard is standing still. Rather, it refers to that the affordance exists regardless, the lizard just has to find a way to overcome the constraints placed on it by the affordances of itself, water and gravity in order to actualise the affordance that surface tension inherently has. Constraints and restraints thus are the limits of the compatibilities between different physical properties of agents, objects and environment, are themselves consequences of those physical properties and are able to be overcome by displacing physical properties of either.

A temporal argument for the necessary omnipresence of affordances can be introduced here; the world existed before life developed. The invariants in the environment were necessary for biological life-forms to exist at all. Additionally, the invariance of the environment enabled a stability that could result in generations of life-forms, underlying evolution (Gibson, 1986). The development thereafter has resulted in several different sensory modalities in different animals, and unless there were different types of invariant energy arrays, we would not see animals developing different sensory modalities. I.e. for auditory senses to develop phylogenetically there needs to be the information pick-up-able, and, this needs to provide an advantage to survivability and reproducibility ontogenetically, for it to manifest phylogenetically. For example, if air did not compress and decompress, there would be no advantage to, expensively, maintain cells that respond to such a thing. It should now be clear that we have to be minimalistic when it comes to ontology, otherwise we jeopardise not only the realist assumptions but also its value to us scientifically. Either way, we still need to assess relationships, because they are absolutely essential in explaining *how we come in contact with* affordances.

Epistemology of affordances. Epistemology is where we can explicate *how* things work, connect and interact without bothering about falling to idealism. For the case of affordances, we can define them epistemologically through information. While information has been defined several times before, it is only relevant here to introduce the most recent one. It is proposed by Golonka (2013) that "Information [refers] to any structure in an energy array that precipitates behaviour in an organism.". It should be clarified here that the first part of the sentence is the ontological assumption "any structure in an energy array" and the second part refers to (a part of) the epistemological definition of information. The second part cannot be ontological, because, if the existence of information depends on it having consequences for something else, then it is necessarily a relationship-dependent concept and as mentioned, this is unsatisfactory. But, a correction, or clarification, needs to be made to this definition also; “precipitating *behaviour*” can become troublesome if one perceives information but do not act upon it. For example, if someone is sitting and eating a plate of food and suddenly there is a threat in the room, Barrett (2011) would have it that now the food no longer affords eating, but this is a misconception. The food *is* edible still, but our most likely behaviour is to respond to the threat. We *can* keep eating the food; it would just probably result in a negative consequence. Consequences cannot decide which affordances exist or not, only, perhaps, change in behaviour. This relates back to precipitating behaviour, in that, it would have to depend on the definition of behaviour. It would be better to err on the side of caution by defining it as precipitating *perception*. Not in a causal manner, but in a complementary manner. We can thus ask the epistemological question, how do we come in contact with affordances? Through perception of structure in the ambient energy array. Perception and structure here also needs a definition, Golonka provides this also (2013); “...perception [is] the apprehension of structure in an energy array where 1) the structure is specific to an event or property in the world, 2) where the meaning of the structure (for that organism in that task) is about that event or property (i.e., a dog’s bark is about the event of a barking dog), and 3) where the meaning of the structure must be learned (or, more correctly, where an organism must learn how to coordinate action with respect to this structure).”. With these definitions in place, it should be clear that we come in contact with other agents, objects and the environment through the senses, leading on to direct perception. This clarification of the definition of affordances should lead you to the insight that relationships, is a necessary definition of information and thus of affordances, *epistemologically*.

We can, through the definitions above, meaningfully talk about affordances as relationships between compatible agents, objects and the environment without worry. In conclusion, ontologically, it does not make sense to talk about affordances to be existent or not, through extended mind arguments the possibility to overcome limitations is solely dependent on the limits of our imaginations, non-temporal-restriction and thus change in physical properties in agents, objects and environments. Epistemologically, it makes sense to talk about affordances to be present or absent, because an object is X-able to us only if it reflects structure and we are perceiving it. If an object is X-able to us or not, is thus dependent on direct perception, information, affordances and the limitations for both all physical properties involved, as well as the consequence of the relationships and interactions between all parties. Under this definition of affordances, it affords us vast scientific exploration and production of hypotheses and predictions.

Research and Methodology

Wilson and Golonka (2013) structures the approach to experimenting by four key questions, termed the “task analysis”. Firstly, what is the task to be solved? They argue that embodied cognition solutions solve specific tasks, so we need to identify the task to be solved because it will identify how an agent produces appropriate behaviour in the situation. Secondly, which resources do agents need access to in order to solve the task? The resources, argued from embodied cognition, are the brain, body, environment and the relationships between these things. An exhaustive list of resources should be formalized for each task, in this way tasks are able to be differentiated from each other, and, done so in terms of their underlying dynamics (for example Bingham, 1995). Thirdly, how can the resources be combined in order to solve the task? The required resources needs to be assembled into a dynamic system that solves the problem in real-time. An important point made by Wilson and Golonka (2013) is that “since we only have access to information about our bodies and the environment via perception, an embodied analysis must include a detailed account of the perceptual information used to connect the various resources” (p. 3). Fourthly, does the organism actually assemble and use these resources? The hypothesised dynamical system in step three may not be accurate and this is an empirical question. One of the basic tools suggested is perturbation; “systems respond to perturbations of resources in a manner that is specific to the role that resource[s] play in the system” (p. 3). The thesis experiment, also follow these guidelines and can thus act as a practical application, and example, of the task analysis. However, it is necessary first to introduce the content of the chosen field of empirical research, computer gaming. There is good reason to do so because of the basic issue of information and affordances through depictions (non-existent in one sense, Gibson, 1986) and also because this argument is used to deter experimenting on screen-presented stimuli. It should be mentioned however that it is under discussion exactly what it is a depiction informs of/affords (Wilson, 2013).

Electronic Sports and On-screen Research

The world of electronic sports (henceforth; e-sports) is a largely unexplored area even within traditional cognitive psychology. In rECS it would be discounted, essentially, because it is performed on a screen and as such does not provide affordances per se. In agreement with this, you still cannot just ignore this field. It is not only entertainment; it is for some a way of life and it is for others their monthly income -both as creators as well as players. In an attempt to refrain from legitimising the field further, it stands for itself in the amount of hours played, the number of games produced, the amount of profit for gaming-companies and the prize-pools for e-sports players. One aspect however, that is unstated in the relevant literature, is that unbeknownst to producers and programmers of games, their absolute central aspects follow exactly that of ecological psychology and rECS. Indeed, Gibson (1986) made the same analogy for the fields of architecture and design.

A programmer creates the environment in which a player is to exist and, hopefully, immerse herself. The virtual environment is created in respect to contain virtual affordances for the player, or for the player to explore and act within. The evolution of computers, as well as the games played on these computers, has increasingly dealt with the fact that players expect more and more virtual affordances to be available to them. There is an expectation to be able to do more things, to increase the complexity of the virtual environment, virtual objects and virtual agents. When expansions are released for already popular games, they account for this fact by not only adding new items, for example in MMORPGs (massively multiplayer online role-playing games), but also by creating new virtual affordances to players through new virtual behaviours and game modes (changing virtual affordances of the already known game), allowing even more completely new virtual behaviours and thus making the virtual environment increasingly complex. For games that insist on reflecting reality, the expectation is that virtual affordances should more and more closely resemble the environment. This is thus an essential area to account for when it comes to rECS and psychology in general. It is necessary however to introduce the term virtual affordances, because as stated, pictures, depictions and even movies do not present affordances (Gibson, 1986 and Wilson & Golonka, 2013, although see Wilson, 2013, for a discussion on the topic). Nevertheless, computer gaming industry works with manipulation of virtual affordances, and thus, virtual affordances needs an, at least temporary, definition; virtual affordances are *invariants programmed in environment, objects and agents, allowing, limiting or disallowing virtual behaviours, interactions and coupled systems between those environments, objects and agents*. Necessarily, all the appropriate concepts apply, for example the visually perceptible virtual environment presented on-screen and any ambient auditory array presented through the sound-system and so on.

The game of choice for exemplification (not used for experimentation, however), is League of Legends (launched 2009, by Riot Games, formed in 2006). It is played by 32 million unique players every month, 12 million of which play daily, racking up 1+ billion hours of play each month making it the most played computer game in the world (Riot

Games, 2012). They have created a virtual environment in which there is an economic system; killing AI-agents and opponents grants money, from which you may buy items to further enhance your character's basic, level-dependent, properties. The virtual environment affords movement in two dimensions but also limits movement by walls and shrubbery. Each character, 110+ to choose from, is afforded five specific abilities (one passive, meaning it is not "usable" by pressing a button and four active abilities assigned to one key each) plus the choice of two out of thirteen that are common to all players. Some abilities modify movement capability of oneself, of other agents, amount of damage given, amount of damage taken and/or regeneration of vitals (health, mana or for a few characters, a specific other vital coupled to its offensive and/or defensive abilities). Two teams with five players on each team thus comprises 100 agent-specific virtual affordances, coupled with the dynamic variety in which the virtual environment lends itself to each specific character. Needless to say, perceiving one's own and other characters' virtual affordances, in which sequence they are used, in which situation, where one is situated in the virtual environment and all agents' vitals, is what counts as skill in this game. It is a visual perception heavy game but auditory perception enables you to gain information on parts of the virtual environment not currently in your virtual visual field. The mentioned variables are far from an exhaustive list; there are quite many more virtual affordances to be described, but these should be enough for even the most computer-illiterate to understand that it is far from a simple virtual environment to navigate through successfully. Thus, this complexity gives rise to a vast range of behaviours and emotions, one of the most extreme of which is called "rage-quitting". It is when you are sufficiently angry, regardless of why, that you exit the game before completion (most often spouting abuse) and leave your team severely underpowered against the opponents.

Computer-gaming, or virtual environments, although not adhering to the strict definitions of rECS, needs to be accounted for. It is suggested that it is sufficient to discriminate between real life and gaming by the verbal notation *virtual*. When experimentally reporting on computer games or screen-dependent research, it is of great importance to include an exhaustive list of variables and virtual affordances in the, previously mentioned, task analysis. The study at hand attempts to follow the task analysis for rECS experimentation, in order to show its practical application. That is, to try and create headway for on-screen experimentation by refuting the unwillingness within the embodied perspective towards it; discriminate between computational and ecological strategies and; illuminate how lucrative future research can be on the basis of both the specific research presented and, more generally, to produce an empirical basis for Ecological Psychology.

Experimental Abstract

Establishing an empirical basis for ecological psychology is a central endeavour of its research program (Shapiro, 2011). Screen-based research is not entirely on terms with concurrent discussions of what it is that depictions afford and/or inform agents of (Wilson, 2013). However, regardless of theoretical status, it is important to provide an experimental basis for this type of research. The study at hand provides both an example of this and a broader case for the inclusion of screen-based research. Participants were to intercept an object by controlling angle and speed of a second object, resulting in trails of the trajectory taken to do so. It was hypothesized that an ecological strategy would be employed over a computational strategy. The results support the hypothesis and also demonstrate that empirical observations are derivable from screen-based research. Importantly, limitations in the current study suggest lucrative future research, promising to provide clearer and more ecologically valid results in the endeavour to provide empirical bases for ecological psychology.

Contrasting Computational and Ecological Strategy in a Virtual Interception Task

Experimenting with screen-presented material is practically convenient, cost-effective, time-effective and participants are most often both computer literate and comfortable using computers. Inconveniently, screen-presented stimuli are somewhat incongruent with Ecological Psychology (Gibson, 1986) and radical Embodied Cognitive Science (Chemero, 2007). Gibson explicitly states that depictions of an object do not afford an agent what the actual object does, and there is agreement from theorists such as Wilson and Golonka (2013). A main reason may be that Ecological Psychology relies on movement of organisms and a dynamic relationship between environment, body and brain. Depictions are thus very limited in what type of interaction they offer. While depictions do not hold affordances for organisms, the most recent discussions invite depictions to still contain information[11] (Wilson, 2013). This is not as intuitive as one might be led to believe and work is still in progress to understand what depictions do and do not afford/inform of. However, computers are a natural part of human lives, used widely in empirical experimentation and are thus necessary to account for.

Whilst the debate about what depictions afford or inform of is still in its infancy, it is still necessary to hold a working definition of what we do in front of computer screens. There is thus a need for a distinction between what we perceive on a screen and in the environment. The lingual notation *virtual* should be of central focus, which denotes that it is something that exists outside of the environment but is an environment in and of itself. This is to say that, had we actually been a virtual agent in the virtual environment, then we would simply be agents in an environment. However, since we already are agents in an environment, we can only ever be said to immerse ourselves in a *virtual environment* as *virtual agents*. It is also important to note that *virtual* connotes *created*[12] or *programmed*[13], because they only mimic the environment and agents to some degree and this is decided by the creators[14] of those virtual components. A focus on programmed components will be pursued here, and is to mean a virtual environment that most often is subject to exploration and movement in a

[11] Information here is defined as ”any structure in an energy array that precipitates behaviour in an organism” (Golonka, 2013).
[12] *Created* refer more so to non-programmed depictions, such as art, photography and film (and are thus more likely to be a part of the environment).
[13] *Programmed* refer more so to computer-based coding (and are thus more likely to constitute the virtual environment).
[14] Indeed, certain games such as Portal (Valve Corporation) attempt to create virtual environmental laws close to the environment, but pushes the boundaries of laws of movement as far as possible.

similar manner to how we navigate our environment. A main point of divergence is that virtual environments require only small movements of an agent's hands and eyes. What-is-perceived however is more closely analogous to an environment, with the obvious limitation of the physical end of the screen.

Intercepting objects is not a novel idea and have been attempted to be used in embodied psychology experiments earlier. Montagne et.al. (1999) had participants intercept a moving ball in an apparatus, finding that the prospective strategy proposed by Bootsma et al. (1997) accounted for the obtained kinematic results. The present study uses a similar type of reasoning: The task is to intercept a rectangle that is moving from the top left to the top right side of the screen by controlling movement of a circle beginning in the lower left side of the screen. The resources available in this task are the continuous movement, and perception, of rectangle and circle in the virtual environment and controlling angle and speed of the circle. In turn, this invites different types of strategies to solve the task and these are traceable to different antecedent assumptions. "Computational" assumptions would compare brain-activity to computation, this leads to a strategy in this specific task which would rely on calculating (based on the speed and initial angle of both objects) a point further to the right on the screen where a possible interception point may be. This strategy would result in the circle's trajectory looking like a straight line, from its starting point on the bottom left of the screen towards a possible interception point in the upper right of the screen. "Ecological" assumptions however lead to a different strategy. They would predict that participants continuously aim towards the rectangle and as they get closer to it, adjust the angle of the circle until it is almost following the rectangle. Using this strategy would yield trajectory arcs rather than straight lines and it is thus possible to visually distinguish between the strategies[15]. It is hypothesized that participants will use the ecological strategy to a larger extent than the computational strategy and this will be visible in the data through the resulting trails of the circle's trajectory.

Another point of enquiry is if a temporarily imperceptible object is approached with the same strategy as a continuously perceptible object. Smith (1996) suggests that an occluded object needs to be represented in order to be tracked[16]. Therefore, a second condition was created with the rectangle programmed to fade in and out intermittently, causing it to be temporarily imperceptible. If Smith's proposition is accurate, we should see

[15] The computational type strategy is also referred to as a predictive strategy and the ecological strategy as a prospective strategy (Bootsma, 1991).

[16] Also called non-effective tracking.

large differences in which strategy is chosen depending on condition. Since radical Embodied Cognitive Science (Chemero, 2007) dictates that representations do not exist, it is hypothesised that there will not be large differences between conditions on strategy chosen.

Method

Participants

A convenience sample of 30 Swedish students from Lund University (12 males and 18 females, M_{age} = 22.6; SD = 2.41) participated in the study. They did not receive compensation for participation and were randomly assigned to one of the two conditions.

Apparatus

A personally developed computer program[17] was running on an MSI laptop, dual-core 2.27GHz with a 15.4” screen. The computer program presented an 800x600px grey window, within which a black rectangle moved from the top left to the top right of the screen and a black circle with a line pointing in the direction of its current movement was presented. The rectangle was programmed to move with constant speed and while the circle always began moving upward, its initial speed varied slightly from trial to trial. Both speed and direction of the circle were able to be controlled by the arrow-keys on the keyboard. In the first, constant, condition the rectangle was visible throughout each trial. In the second, fading, condition the black rectangle was programmed to fade in and out intermittently over the course of its movement over the screen.

Procedure

Participants were informed of the movement of the rectangle and circle and that the goal of the task was to intercept the rectangle with the circle by changing angle and speed by tapping the arrow-keys on the keyboard. They were also instructed that this would be done over 20 trials and upon completion a set of four demographic questions would be asked (age, gender, if they had corrected to normal/normal vision and number of hours per week played in the last three months).

Data collection

The computer program was written to record the trajectory of each trial, age, gender, if they had corrected to normal/normal vision and hours per week played during the last three months. In order to ensure anonymity the results were packaged into a single file and uploaded to a secure FTP-server. The name of the file for each participant was coded in order to ensure that no data were traceable back to any specific participant. The coded files could

[17] Java Applet Programmer: Linus Probert

only be opened with a separate, administrator version of the program, which only the main experimenter has access to. The computational and ecological strategies were defined before any data had been collected and were subsequently used by the second rater to classify trajectory paths. The third type strategy was discovered post hoc, but before the second rater had received any data. Therefore, a third description was added and if a trajectory did not resemble either of the three, they were to be rated as “other”. In SPSS (version 21), frequency of either strategy was recorded per participant along with gender, age and number of hours played per week the last three months. Also, a separate data-sheet was prepared where each trial was recorded along with type of strategy and accuracy (hit or miss). Upon completion of the task, post hoc, all participants were asked if they had used a particular way of solving the task, or developed one over the trials. All participants responded that they did not think of anything specific during the trials and that they just simply tried to hit the rectangle any way they could.

Results

Preparation of Data

All participants had corrected to normal/normal vision and an equal number of males and females were in each condition, this information was thus discarded from further analysis. Age was homogenous and severely restricted in range and was also discarded. Number of hours played was asked in order to control for computer experience, participants were told that any type of game (for example, including Facebook-games) counted. There were no differences between the groups on this variable either (although it varied within groups) and so is not mentioned further. There was some indication of practice effect on accuracy, but not on choice of strategy. Since accuracy only holds a correlational relationship with choice of strategy, practice effect only relates to the central measure by two correlational relationships and thus not considered essential to further analysis.

Classification of Strategies and Inter-rater Reliability

Trajectories were rated as computational if there was a short curve early in the trajectory, followed by a longer straight line. The straight line could include small adjustments to angle close to impact, seen by very small changes in direction. A trajectory was classified as ecological, if it followed a longer arc up until impact. A third variant of trajectory contained an initial smaller arc, followed by a straight line and then by another small arc. Trajectories that did not fit into any of these categories were classified as “other”. Exemplars of each are presented in Appendix A. The inter-rater reliability was calculated on half of the dataset (300 trials) and was found to be Kappa = 0.83 ($p < 0.05$), 95% CI [0.77 ,0.88].

Hypothesis Analyses

Descriptive statistics presented in Table 1 display means indicating that ecological strategy had a higher frequency (317/600 trials) compared to that of computational strategy (154/600 trials), third type strategy (79/600) and other strategy (50/600). Standard deviations show high individual variability in strategy chosen. 56.5% of ecological trials (179/317) were employed in the constant condition, whereas 41.6% of computational trials (64/154) were employed in this condition. A χ^2 analysis of the difference between ecological/computational frequencies across the two conditions was significant, χ^2 (1, n = 471) = 9.22, $p < 0.05$, Cramer's ϕ = 0.14.

Table 1

Means and Standard Deviations (in brackets) of Strategy used (in frequency per participant) by condition and strategy

	Constant	Fading
Ecological strategy	11.9 (5.8)	9.2 (7.5)
Computational strategy	4.3 (3.9)	6 (4.4)
Third type strategy	2.7 (3.2)	2.5 (3)
Other strategy	1.1 (1.5)	2.3 (3.2)

Exploratory analyses

Accuracy was determined by visual analysis of trajectory patterns where a hit was assigned when both the trajectory of the rectangle and circle ended in close proximity to one another. Also, the program was designed to produce the trial number at the end of each trial when either an interception was successful or the rectangle had reached the right hand side of the window. Exemplars of hits and misses are found in Appendix B. Descriptive statistics presented in Table 2 show that ecological strategy gained the highest accuracy. In 63.4% of ecological strategy trials (201/317) the rectangle was successfully intercepted, whereas 31.8% of computational strategy trials (49/154) were successful. A χ^2 analysis of the difference between hit/miss frequencies across the two strategies was significant, χ^2 (1, n = 471) = 41.53, $p < 0.05$, Cramer's ϕ = 0.3.

Table 2

Means and Standard Deviations (in brackets) of Accuracy (in decimal percentages) by condition and strategy

	Constant	Fading
Ecological strategy	0.63 (0.48)	0.64 (0.48)
Computational strategy	0.41 (0.5)	0.26 (0.44)
Third type strategy	0.32 (0.47)	0.29 (0.46)
Other strategy	0 (0)	0.06 (0.24)

Discussion

It was hypothesized that participants would favour ecological strategy over computational, seen by the trail of the circle's trajectory towards intercepting the rectangle. The hypothesis was supported by finding mainly arced trajectories in the dataset as opposed to straight trajectories. The difference found on strategy chosen between conditions had a very low effect size and is not considered to have had an essential effect on choice of strategy. These results speak in favour of reliance on environment and ecological perception and have a bearing on the discussion about effective and non-effective tracking (Smith, 1996, and Chemero, 2007). It was proposed by Smith that non-effective tracking, when something goes out of perception by being occluded, invites representation of the object being tracked. Although the object in this task was not occluded, it can be considered a simile that the rectangle becomes imperceptible intermittently. Smith's theoretical point of view is not entirely supported by the empirical data presented herein. There was only a hint of effect on strategy chosen by condition and, ecological strategy was employed more often than computational in both conditions. There is thus more support for the reasoning Chemero provides for non-representational non-effective tracking, in that it can still be directly perceived. This can be accounted for by considering the term *reliance*. Specifically, perception of the virtual environment is relied upon to remain invariant, it is thus possible to track a temporarily imperceptible object in an effective manner. In terms specific to the current study, a reliance on ecological strategy is still favoured over computational even though the rectangle goes out of perception intermittently.

A third type of strategy arose which was unaccounted for by the task analysis: A few participants switched from one to two arcs. The reasoning provided by these participants was that they tried to make it easier for themselves by first aligning the circle on a parallel path to the rectangle before angling the circle back upwards towards the rectangle. This invites discussion of a possible heuristic in line with ecological theory since the on-going process relies on invariant environmental aspects (simultaneous perception of the rectangle's and circle's trajectory). The case can be made that the simple, yet pervasive, relationship participants interact through is a temporary dynamic coupling to the virtual environment. This suggests that the ecological strategy and the third type strategy share strategic aspects, perhaps a reliance on the same heuristic.

The exploratory analyses on accuracy, reveals that it is higher for ecological trials compared to computational trials. However, although accuracy was lower for computational trials in the fading condition, compared to computational trials in the constant condition, it was still used more frequently in the fading condition. This might suggest that even though accuracy was higher for ecological trials, the higher reliance on this strategy is not necessarily explained by its success. The weak effect size contributes to this perspective and may instead suggest that it is simply more natural to use an ecological strategy. Participants were more likely to succeed if they employed an ecological strategy, perhaps this indicates that using computational norms to compare human behaviour to, are limited here also[18].

Limitations and future research

The program presents a two-dimensional virtual environment and it can be considered too simple to yield a comparison between prospective and predictive trajectories. After all, even if condition was found to have a minor effect on strategy chosen, it doesn't allow ruling out alternative explanations. Although the results speak in favour of an ecological approach, it is necessary to identify that the specific task does not necessarily generalise to real life tasks. Therefore, an issue may be that the virtual environment lacks ecological validity. However, it could lead to pivotal and illuminating future research using screen-presented depictions and contrasting ecology with computation. The current computer-program contains a simple virtual environment where movement is restricted to two axes: Instead, a three-dimensional virtual environment could be programmed and present a first-person perspective from the point of view of the circle, as if one was standing on the ground looking upwards toward the sky. If then a projectile would appear far up in the virtual sky and the goal was to intercept this projectile, it is reasonable to assume that a clear ecological strategy would result. It is hypothesized that in such a situation, one would never leave the projectile outside of one's virtual visual field (i.e. outside of the screen), and would consequently aim

[18] In reference to the discussion in chapter 1 on the limits of the Wason 4-card task (Wason, 1966).

towards the projectile up until impact. This would yield prospective trajectory patterns and ecological validity would be more appropriately accounted for.

Another interesting aspect is that of the third type trial, which requires both theoretical contemplation as well as further experimentation for its explanation. The computer program could be reprogrammed to vary speed, distance or any other aspect of movement to reveal when and why third type strategies occur. Until then, it is assumed that the third type strategy is a complex version of the ecological type strategy and that they most probably share an underlying heuristic.

In conclusion, although the task at hand may lack ecological validity, it still yields empirical observations on terms with Ecological Psychology. Consequently, it provides an argument for the inclusion of screen-presented research and furthermore as a source of empiricism for Ecological Psychology.

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Appendix A

Exemplars of Trajectory Patterns/Strategies

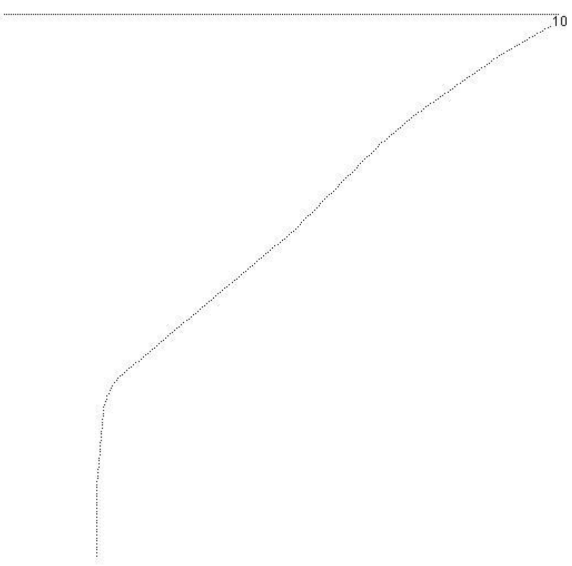

Figure 1. Computational strategy

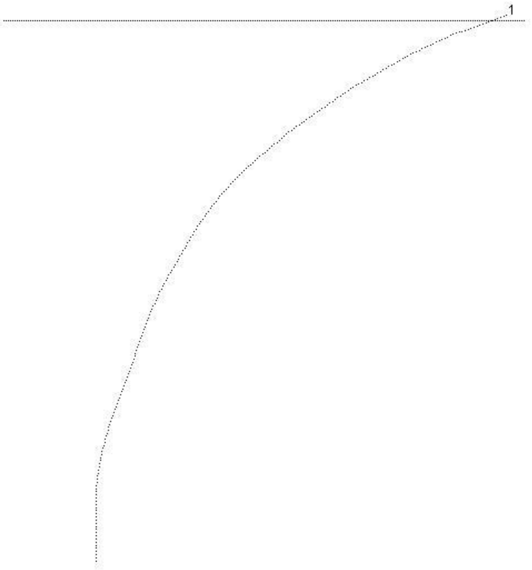

Figure 2. Ecological strategy

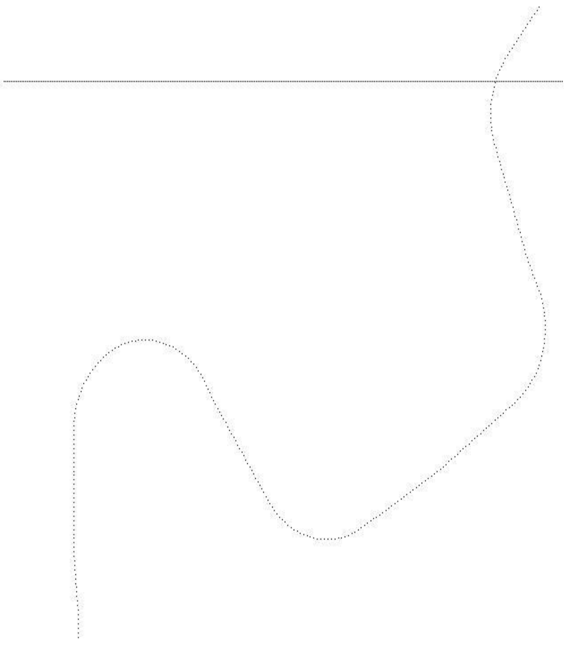

Figure 3. Other strategy

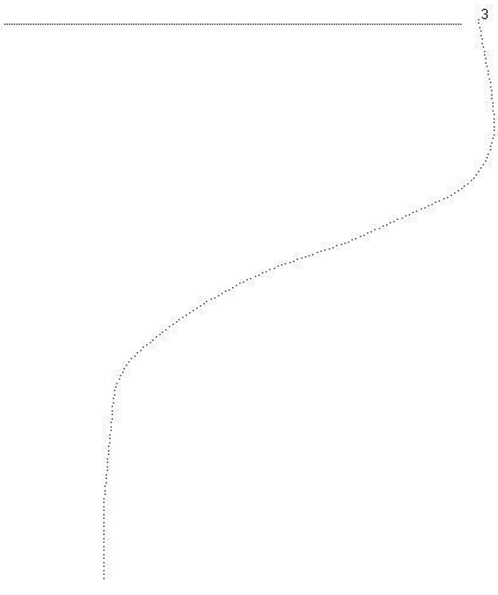

Figure 4. Third type strategy

Appendix B

Exemplars of Interception Success (Hit) and Failure (Miss)

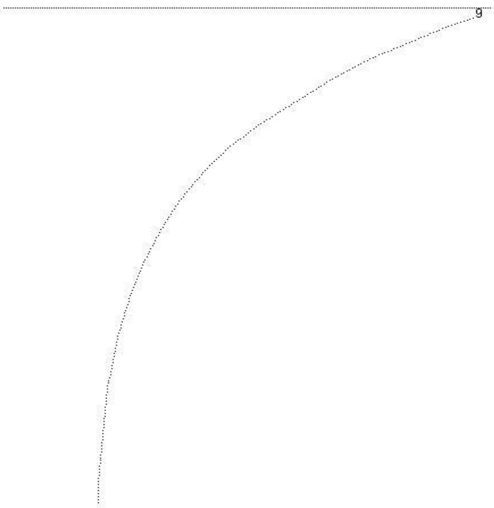

Figure 5. Interception success

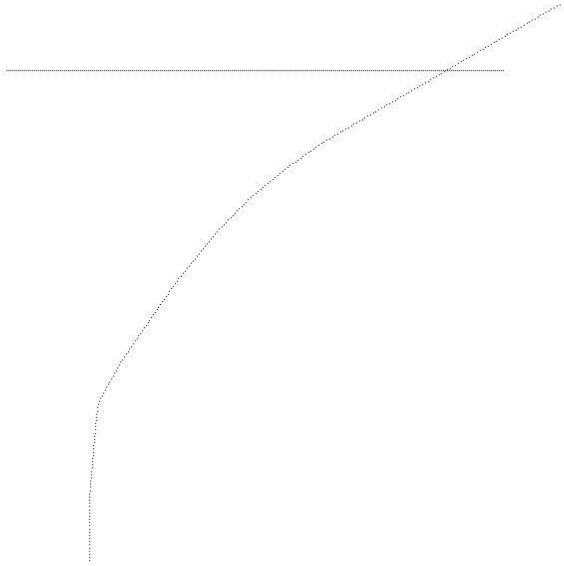

Figure 6. Interception failure

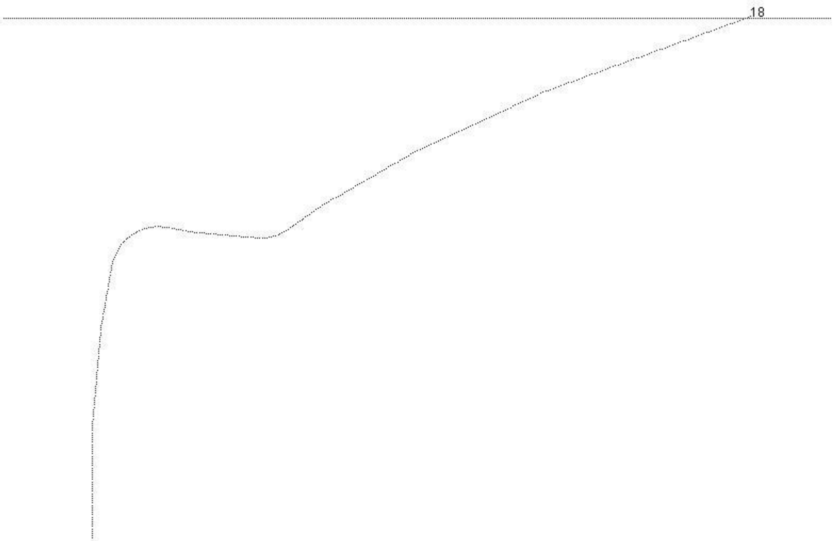

Figure 7. Interception failure

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