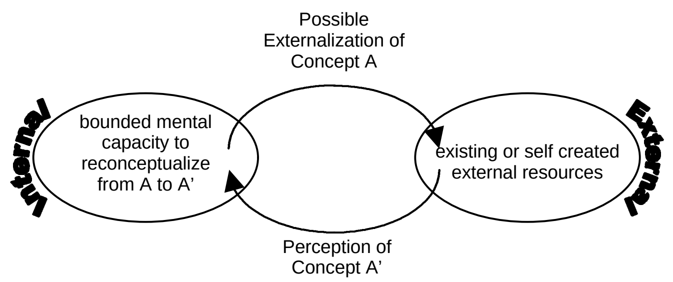
a) A short description of the state-of-the-art at international level showing the context of this proposal

Unconscious boundaries of mind; research into the extended mind hypothesis

Archaeological records of human prehistory witness a sudden cognitive breakthrough; ever since humans became so-called epistemic engineers, i.e. creators of “tools for thinking”, an extraordinary acceleration in our intellectual capacities emerged[1,2]. Without much of a change in our biological underpinnings, the invention, use and elaboration of epistemic tools like pictorial representation evidenced by cave-drawings, heralded an enormous increase in human intelligence. In fact many philosophers, such as Daniel Dennett[6], assert that our special cognitive powers are derived mainly from our ability to extend our minds’ capacities through interaction with our environment. This Extended Mind theory[3] focuses on our capacity to create external (decoupled) resources for reasoning next to internal ones.

Several reasons are brought forward as to why these external resources enhance our intellectual abilities[9]. Next to aids to memory (think of shopping-lists and diaries) and ways of teaching others what you know (books, graphs), it has recently been argued that the interaction with external resources can alter our way of conceiving things[4]. In other words, it has been shown that the interaction can result in more elaborate intelligent conceptions, which were unforeseen and unanticipated before the start of the interaction[11]. Artists who do not construct a finished work in imagination, but rather engage in an iterative sketching process, exemplify this[10]. This illustrates that our cognitive capacities are extended by our perceptual abilities. It, however, also illustrates that our cognitive abilities, and especially our imaginative abilities, do not possess the full-blown potential we are misled to think[7]. In extreme cases, when a total re-conception is needed, reasoning can hardly proceed without the aid of external resources, as many experiments by the PL, amongst others[25], and stories of inventors bear witness. Kekule, the inventor of the benzene ring, for example, was stuck in the understanding of chemicals as consisting of strings, and it was not until he saw snake-like flames (strings) in his fireplace biting their tails and thus forming rings, that he understood he had to abandon the concept of strings in favor of rings. The figure below illustrates the iterative change in concepts through external resources.



In contrast to the sketching artists, Kekule did not create his own external resources, and as a victim of his inappropriate preconceptions, he lingered on until the environment offered him the appropriate conception of a ring. In fact, he even had to wait for the environment to present the inappropriate version for him to appreciate, and then to morph it into an appropriate concept. It follows that such a supportive environment is exceptional, as confirmed by the rareness of occurrence of such AHA-erlebnisses. But even when such an exceptional environment occurs, it most probably reflects cultural circumstances the reconceptualizing person is living in, which has been argued to control the course of the reconceptualization and may even limit its scope[8]. Hence, although an extraordinary acceleration in intellectual achievements may hallmark human evolution since prehistory, our individual short-term prospects are in fact rather depressing because of our intellectual boundaries. That is, unless we acquire proficiency in creating external resources ourselves (like artist sketchers) and then profit from perceiving them in unanticipated ways.

These three elements of respectively mental boundaries to reconceptualize, possibly followed by processes of creation, and finalized by perception of alternatives in the environment, constitute the major issues of the current proposal. In order to get an understanding of the dynamics of this process this proposal focuses on impeding as well as facilitating factors. Impeding factors that will be studied are individual (up to clinical) limits in the mental and perceptual ability to switch concepts (i.e. difficulty in trading concept A for concept A’), while facilitating factors apart from sketching may reside in the inclination of the visual system to switch between perceptual alternatives, because of e.g. neural fatigue or more high-level 'reset'-mechanisms as recently proposed by Leopold and Logothetis[17]. Moreover, culture, as ingrained in person and environment, may limit the scope of the reconceptualization[8]. To make a start at dissecting the influence of such a large-scale system as culture we will investigate reconceptualization of animate (biologically defined) as well as inanimate (culturally defined) objects.

Verstijnen (PL) has studied the boundaries of mind, sketching proficiency and their effect on the acquisition of alternative concepts (re-conceptions)[40]. With Wagemans (PI2), she studied sketching designers[23] and ambiguous figures[41], i.e. figures that can be conceived in two alternative ways (e.g. the figure below in which a rabbit (concept A) or a duck (concept A') can be seen).

While working with these figures she noticed huge individual differences in flexibility to re-conceive. This finding called for an objective measure of flexibility in concept switching, which she created with Wagemans[26]. Moreover, she noted differences between the processing of biological figures such as the duck/rabbit above, and inanimate (culturally defined) figures such as a tent/cake. With Jellema (PI3), who studies the cognitive neuroscience of social behavior, and of autism in particular[32], she just started out research on the idea that there may be a clinical side to extreme inflexibility in re-conception that marks levels of autism, which might be researched, and possibly quantified, through this measure. These ideas parallel recent theories in neuropsychology[28-30,31,33] and philosophy[3-10].

b) CRP aims & objectives (including vision)

The CRP participants share the conviction that successful reconceptualization is orchestrated by a number of interacting factors. The CRP will research how human reconceptualization is continuously taking place through interaction with the environment, and aims at establishing the factors that may facilitate as well as impede such reconceptualization, both in normal and in autistic persons. These factors will be established through both experimental research and computer modeling.

The idea of the necessity/helpfulness of the environment for reconceptualization is, however, subject to dispute. Psychologists adhering descriptivist theories have, for example, argued against one of the hallmark findings, i.e. the finding that only after sketching out the duck/rabbit figure displayed above participants in the experiment could infer the alternative interpretation[21]. Also other researchers[15] have brought forward that when participants are asked to create new objects before their mental eye by combining basic figures such as the capital letters J and D (which can be combined into an umbrella for example), can also lead to inventions. This can be taken to indicate that new non-existing objects can be created before the inner eye, which in turn can be taken as evidence against the necessity to externalize. But as Verstijnen (PL/PI1) has argued before[25], there are different processes at stake here some of which are more supported by externalization than others.

More in general, it is the vision of the CRP that creative reconceptualizations are subserved by various mental processes, which may dynamically interact with each other and with the environment[35], and may not necessarily be subject to the same impairing and facilitating factors. Even when they are influenced by the same factors, it would not necessarily have to be to the same degree. Some impairing and facilitating factors are mentioned above; individual differences, proficiency in sketching, others we expect to emerge during the project and each may have a differential impact on the processes involved in reconceptualization.

c) Strategy and work plan

The PL will take care of the smooth functioning of all project activities through coordination of the activities within the project, and will look after the overall legal, contractual, ethical, financial, and administrative management and will guarantee timely and adequate reports to the EC. She will first of all draft a consortium agreement, a detailed work plan and a management plan, which will be discussed with the other participants before CRP take-off. The work plan will contain the following. A to-be-selected candidate for the PhD and Post-Doc functions need to be approved by every PI before admission to the CRP. This to make sure that the future CRP participant shares enough common ground with the other PI's other than his/her own direct supervisor to ascertain straightforward communication among all CRP-participants. Subsequently, in order to frequently discuss recent results as well as to profit from each other's knowledge and expertise in finding out new routes to take, meetings need to take place every 4 months. These meetings will preferably take place at alternating locations so that each time another researcher will have the opportunity to demonstrate his/her laboratory arrangements to the other researchers (i.e. contributing partners and their PhD students or Post-Doc researcher). For the sake of more regular dissemination of results and other (more general) information a website (blackboard system) will be created on which each partner can upload and download the(ir) latest information. The work plan will further include timing of the deliverables and milestones as stated below. The management plan will include attitudes and stances toward deviations from the work plan, property rights, and internal conflicts.

d) A short bibliography supporting the scientific case

Archaeological arguments concerning the Extended Mind hypothesis

1. Humphrey, N. (1998). Cave art, Autism, and the Human Mind. *Cambridge Archaeological Journal,* 8, 165-191.
2. Mithen, S. (1998). The supernatural beings of prehistory and the external storage of religious ideas. In C. Renfrew & C. Scarre (Eds.). *Cognition and material culture: the archaeology of symbolic storage* (pp. 97-106). Cambridge: McDonald Institute.

Philosophical arguments concerning the Extended Mind hypothesis

3. Clark, A. (2000). *Mindware: an introduction to the philosophy of cognitive science*. Oxford: Oxford University Press.
4. Clark, A. & Chalmers, D. (1998). The extended mind. *Analysis*, 58(1), 7-19.
5. Currie, G. & Ravenscroft, I. (2002). *Recreative Minds: Imagination in Philosophy and Psychology.* Oxford: Oxford University Press.
6. Dennett, D. (2000). Making tools for thinking. In D. Sperber (Ed.). *Metarepresentation: A multidisciplinary perspective* (pp. 97-106). Oxford: Oxford University Press.
7. Pylyshyn, Z. (2004). *Seeing and visualizing: it's not what you think.* Cambridge: MIT press.
8. Sperber, D. (2001). Mental modularity and cultural diversity. In H. Whitehouse (ed.), *The debated mind, evolutionary psychology versus ethnography.* Oxford: Berg.
9. Sterelny, K. (in press). Externalism, epistemic artefacts and the extended mind. In R. Schantz (Ed.). *The externalist challenge. New studies on cognition and intentionality*. Berlin; De Gruyter.
10. Van Leeuwen, C., Verstijnen, I., & Hekkert, P. (1999). Common unconscious dynamics underlie uncommon conscious effects: a case study in the interaction of perception and creation. In J. Jordan (ed.), *Modelling consciousness across the disciplines.* Lanhan, MD: University Press of America.

Empirical research concerning the Extended Mind hypothesis

11. Chambers, D. & Reisberg, S. (1985). Can mental images be ambiguous? *Journal of Experimental Psychology: Human Perception and Performance*, 11, 317-328.
12. Claessens, P. M., & Wagemans, J. (2005). Perceptual grouping in Gabor lattices: proximity and alignment. *Perception & Psychophysics,* in press.
13. Craver-Lemley, C., & Reeves, A. (1997). Effects of imagery on vernier acuity under conditions of induced depth. *Journal of Experimental Psychology: Human Perception and Performance, 23,* 3-13.
14. Finke, R.A. & Shepard, R.N. (1986). "Visual Function of Mental Imagery." In K.R. Boff, L. Kaufman, and J.P. Chichester (Eds.), *Handbook of Perception and Human Performance.* John Wiley & Sons.
15. Finke, R.A., & Slayton, K. (1988). Explorations of Creative Visual Synthesis in Mental Imagery. *Memory and Cognition,* 16, 252-257.
16. Leopold, D.A., Wilke, M., Maier, A., & Logothetis, N.K. (2002). Stable perception of visually ambiguous patterns. *Nature Neuroscience, 5,* 605-609.
17. Leopold, D.A. &. Logothetis, N.K. (1999). Multistable phenomena: Changing views in perception. *Trends In Cognitive Sciences*, 3, 254-264.
18. Kubovy, M., & Wagemans, J. (1995). Grouping by proximity and multistability in dot lattices: A quantitative Gestalt theory. *Psychological Science, 6,* 225-234.
19. Kubovy, M., Holcombe, A. O., & Wagemans, J. (1998). On the lawfulness of grouping by proximity. *Cognitive Psychology, 35,* 71-98.
20. Maier, A., Wilke, M., Logothetis, N.K., & Leopold, D.A. (2003). Perception of temporally interleaved ambiguous patterns. *Current Biology, 13,* 1076-1085.
21. Peterson, M.A., Kihlstrom, J.F., Rose, P.M., & Glisky, M.L. (1992). Mental Images Can be Ambiguous: Reconstruals and Reference Frame Reversals. *Memory and Cognition,* 20,107-123.
22. Verstijnen, I.M. (2005). Priming of ambiguous figures. Oral presentation given at the 10th European Workshop on Imagery and Cognition at St. Andrews, Scotland, and manuscript submitted.
23. Verstijnen, I.M., Heylighen, A., Wagemans, J., & Neuckermans, H. (2001). Sketching analogies and creativity. In J.S. Gero,, B. Tversky and T. Purcell (Eds.), *Visual and spatial reasoning in design.* Key centre of Design Computing and Cognition, University of Sydney, Australia, pp 299-310.

24. Verstijnen, I.M., & Schoon, M. (2001). Expert problem solving: fixation or creativity. Poster presentation given at the 9th European Workshop on Imagery and Cognition at Pavia, Italy, and manuscript in preparation.
25. Verstijnen, I. M., Leeuwen, C. van, Goldschmidt, G., Hamel, R., & Hennessey, J. M.(1998). Creative discovery in imagery and perception: Combining is relatively easy, restructuring takes a sketch. *Acta Psychologica*, 99, 177-200.
26. Verstijnen, I.M. & Wagemans, J. (2006). Paper-and-pencil sketching: a spontaneous and gradual supplement to sudden insight. Manuscript submitted.

Arguments from neuro-developmental disorders and (non-human) primate studies for the Extended Mind hypothesis

27. Baron-Cohen, S., Wheelwright, S., Skinner, S., Martin, J., & Clubley, E. (2001). The Autism Spectrum Quotient (AQ): Evidence from Asperger syndrome/high functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders*, 31, 5-17.
28. Brothers, L. (1990). The social brain: a project for integrating primate behavior and neurophysiology in a new domain. Concepts in Neuroscience, 1, 27-51.
29. Dunbar, R. (1998). The social brain hypothesis. *Evolutionary Anthropology*, *6*, 178-190.
30. Frith, C. D. & Frith, U. (1999). Interacting Minds. A Biological Basis. *Science, 286*, 1692-1695.
31. Humphrey, N. (1998). Cave art, Autism, and the Human Mind. *Cambridge Archaeological Journal,* 8, 165-191.
32. Jellema, T., Lorteije, J., Van Schaffelaar, E., De Haan, E. H. F., Van Engeland, H. & Kemner, C. Failure to automate the processing of social cues in autism. *Neuropsychologia* (in press).
33. Kleinhans, N., Akshoomoff, N., & Delis, D.C. (2005). Executive Functions in Autism and Asperger's Disorder: Flexibility, Fluency, and Inhibition. *Developmental Neuropsychology*, 27, 379-401.

Other references from Section A

34. Bartram, D. (1974). The role of visual and semantic codes in object naming.*Cognitive Psychology*, 6, 325–356.
35. Bechtel, W. (1998). Representations and cognitive explanations: assessing the dynamicist's challenge in cognitive science. *Cognitive Science*, 22, 295-318.
36. Berlyne, D.E. (1971). *Aesthetics and Psychobiology*. New York: Appleton-Century-Crofts.
37. Boselie, F. (1983). Ambiguity, beauty, and interestingness of line drawings. *Canadian Journal of Psychology,* 7, 287-292.
38. Kerkhof, I., Verbeke, E., Peeters, W., Bijttebier, P., Steyaert, J., & Wagemans, J. (2005, August). The perception of facial expressions in children with autism spectrum disorders. 28th European Conference on Visual Perception (ECVP), A Coruna, Spain. Abstract published in Perception, 34 (Supplement), 169a.
39. Long, G. M., & Toppino, T. C. (2004). Enduring interest in perceptual ambiguity: Alternating views of reversible figures. *Psychological Bulletin*, 130, 748–768.
40. Verstijnen, I.M., van Leeuwen, C., Hamel, R., & Hennessey, J.M. (2000). What imagery can't do and why sketching might help, *Empirical studies of the Arts,* 18, 162-182.
41. Verstijnen, I.M. & Wagemans, J. (2004). Ambiguous figures: Living versus nonliving objects. *Perception*, 33, 531-546.
42. Verbeke, E., Peeters, W., Kerkhof, I., Bijttebier, P., Steyaert, J., & Wagemans, J. (2005). Lack of motivation to share intentions: Primary deficit in autism? (Commentary) Behavioral and Brain Sciences, in press.

e) Deliverables and/or milestones

Deliverables

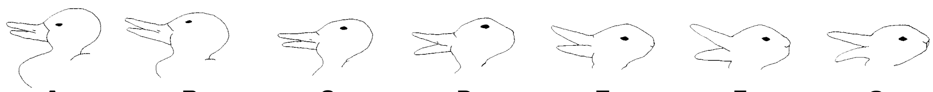
1. a consortium agreement
2. a detailed work plan
3. a management plan
4. interactive website (blackboard system)
5. consortium meetings
6. design of and reports on empirical studies on reconceptualization in normal persons
7. computational framework of reconceptualization
8. design of and reports on empirical studies on reconceptualization in autistic persons
9. progress reports
10. final report

Although the standard approach to just about any topic in cognitive science traditionally involves experimentation, computational modeling and analyses of patient behavior, this proposal includes these three approaches for more intricate reasons. In order to understand these reasons, it is necessary to point out the fact that reconceptualization by means of perceiving objects and processes in the outer world *in an alternative way* is in fact rather counterintuitive, since it involves a diversion from the idea that objects in the environment should be properly recognized for human beings to survive. For example, we should recognize an approaching tiger as such, and better do so rather quickly, rather than to reconceptualize and face the harmful consequences. Fast and accurate object recognition is a natural property and therefore has constituted one of the more prominent research goals in cognitive science.

It is clear that this proposal deviates from this classical research goal, but it does so not by rejecting the standard research methodologies and paradigms, but instead by studying the *exceptions*. In other words we are not interested in straightforward object recognition, but rather in the circumstances that interfere with such recognition in such a way that objects can be conceived in other ways than those dictated by the personal history of the observer.

Visual repetition-priming is a classical tool to assess the nature of object recognition in humans[34]. The term visual repetition priming refers to the phenomenon that the identification (often assessed by naming) of a briefly presented picture of an object is faster and more accurate on its second presentation than control items not initially shown. The nature of object recognition has typically been studied by varying the commonalities between the first presentation (the prime) and the second (the target), and measuring the effects on the velocity and correctness of identification.

The literature on priming of ambiguous figures (i.e. figures that can be conceived in at least two different ways) reveals interesting information for our purposes. It reveals that the perceptual history of the viewer may determine the categorization of the object that is viewed. It has been shown[39] that *short* priming with e.g. a picture of an unambiguous full-blown duck (see Figure A below) will cause an ambiguous target e.g. a Duck/Rabbit figure (Figure D below) to be categorized as a Duck. However, when the Duck picture is looked at for a relatively *long* time this will cause the very same ambiguous figure to be differently categorized as a Rabbit. This latter effect is called interference and is thought to result from neural fatigue of those neural channels engaged in processing the commonalities between prime and target; the commonalities in this example being the duck-aspects of both prime and target. Even an ambiguous figure normally categorized as a duck (e.g. Figure C below) may be categorized as a rabbit because of interference of the perceptual history of a full-blown duck. Hence perceptual history may cause categorizations away from the usual, thereby causing reconceptualization.



A	B	C	D	E	F	G
100% Duck 0% Rabbit	80% D 20% R	60% D 40% R	50% D 50% R	40% D 60% R	20% D 80% R	0% Duck 100% Rabbit

For the study of reconceptualization one of the relevant questions is therefore how the *perceptual history* steers the categorization of a next figure. We will return to the effect of perceptual history later, for now it is important to realize that next to perceptual history we also need to investigate what may be called the *conceptual history.* In other words, we need to investigate how previous (memorized) conceptions steer our categorization. And again how this steering process can result in a categorization away from the usual categorization, i.e. in a reconceptualization. Conceptual history plays a major role in the Kekule example. We need to ask how could it be that Kekule while understanding chemical strings as the only available chemical structure (i.e. previous conception) and while seeing flames (i.e. usual categorization) nevertheless ended up with benzene rings (i.e. innovative categorization/reconceptualization). Clearly there is more at stake here than the perceptual history which in this case probably constituted of the flames is his fireplace; Kekule has been projecting his initially faulty conceptions onto these flames, and this offered him an alternative conception of organic chemicals as consisting of rings.

The experimental literature is however less promising when it comes to the influence of conceptual history on reconceptualization. Mental imagery, the ability to visualize memorized items in their absence, is generally thought to have an adaptive function in the sense that it prepares us for upcoming visual events in the environment[14]. In other words, imagery will cause faster and more accurate perception of *what was already expected to be seen*. But when the conceptual history only speeds up the usual categorization, the external world would *initially* only confirm what we believe to be there and Kekule would have only been confirmed in his faulty conception of string structures.

The picture that emerges from this admittedly short and incomplete tour in the literature is the following; initially the conception of the external world agrees with our conceptual history and is therefore shaped by our expectations, while only later on, after prolonged viewing, perceptual processes like neural fatigue may come into play and may help to reconceptualize. But viewed this way, the critical question emerges as to

Why would we engage in prolonged viewing of a scene that confirms our expectations?

There are several possible answers to this question, and by providing these one by one, we'll come across the various contributions of each PI to the CRP.

The first answer concerns a mere rejection of the adaptive function of imagery as the sole function of imagery possesses. However, just a handful of experiments argue for a different role of imagery, i.e. a disturbing or interfering role. Mostly Craver-Lemley[13] repeatedly revealed interference by imagery. Also the PL of this CRP has recently shown that with imagery priming, just as with perceptual priming, both facilitation and interference effect may occur[22]. However, most interestingly, with imagery the pattern starts out with interference on the very short run (up to 200 ms) and then quickly turns to facilitation. Hence imagery or expectation in the broader sense may indeed smooth the progress of perceptual categorization, but not without briefly impeding it. The project that Verstijnen (PL) will supervise aims to elaborate on this finding. As indicated above, the nature of object recognition is traditionally researched by selective visual repetition priming. In fact, the PL will convert this approach into one that investigates conditions and parameters of priming by imagery for assessing not just facilitation of object recognition but specifically interference of object recognition, since this entails reconceptualization. She will use the ambiguous figures from the Verstijnen & Wagemans[26] studies, as displayed above, since these entail different levels of ambiguity, which allows for disentanglement of interference and facilitation effects.

A second answer to the question why we would engage in prolonged viewing of an object or scene that initially confirms our expectations, may reside in perceptual reset mechanisms such as the one proposed by Leopold and Logothetis[17]. There may be no need for prolonged viewing, i.e. waiting for the neural channels involved to get fatigued, if such a high-level mechanism exists. One of the intriguing outstanding questions that this proposal hopes to answer is whether the short-term interference by imagery as described above may in fact be a manifestation of such a high-level reset mechanism since it occurs at a shorter timeframe than is generally reported to be necessary for the creation of images. But a high-level reset mechanism cannot fully explain all the phenomena around perceptual reversal that have been reported in the literature as even Leopold and Logothetis acknowledge[16]. The project supervised by Wagemans (PI2, Leuven, Belgium) will explicitly focus on the relative contribution of several of these perceptual processes to reconceptualization. In other words it will investigate how our perceptual system aids in trading concepts. Notice that prolonged viewing of the duck/rabbit figure leads the initial interpretation (e.g. duck) to be traded for the alternative and back and forth. The tempo of switching between perceptual alternatives has been shown to be subject to many influences ranging from low-level sensory information such as neural fatigue, to high-level non-sensory information such as cognitive flexibility (reset-mechanisms) and expectancy. Wagemans who has an extended history in researching processes affecting perception of ambiguous dot lattices[12,18-19], will investigate how several influences interact by performing experiments on human subjects and simulations with computational models of the psychological processes and the neural mechanisms underlying them.

A third answer may be related to findings from earlier studies by Verstijnen (PL/PI1) where the participants were deliberately made to think of ‘wrong’ concept A and were subsequently asked for the alternative concept A’. Both novice and expert sketchers spontaneously started to sketch under these circumstances and revealed concept A' from their externalized images, but they generally did not sketch under those circumstances where they were provided with the right concept (i.e. A’ coincided with a memorized item). Surprisingly, when asked for it afterwards, the participants were unaware of the existence of right and wrong concepts in the experiments. This may be taken to indicate that some unconscious trigger may exist that originates from the 'wrong' concept and that urges us to look for alternative concepts in our (self-sketched) environment. At least for external images such an invitation to look for alternatives has been suggested earlier; visual patterns such as good works of art are clear examples, and interestingly so perceptual ambiguity figures in many major theories of aesthetic appraisal[37]. More specifically it is stated that ambiguity is conducive to aesthetic preference[36]. Hence a third answer to the question why we would engage in prolonged viewing of an object that initially confirms our expectations may reside in that certain external but maybe also internal visual patterns (especially ambiguous ones) may invite perceptual exploratory behaviour[36]. This exploratory behavior then may create the time necessary for several perceptual processes to take off and offer alternative conceptions. Since they offer a nice variation in level of ambiguity Wagemans (PI2) will also study the same ambiguous series as presented above.

But there is more to this last answer than just invitations for exploratory behavior instigated by perceptual patterns. The research described above suggested further that not every participant seems to accept this invitation for exploratory behavior as efficient or eager or capable as others might do; although the majority of participants in the experiments, novices and experts alike, started sketching when asked to conceive an alternative concept, not every participant was similarly capable of discovering the alternative concept in his/her sketches. After eliminating differences in proficiency and resulting quality in sketching, we were faced with the possibility that there might be large individual differences in the flexibility to re-conceive. The re-conceptual flexibility measure we created to test this assumption could indeed account for a considerable part of the variability amongst participants in follow-up experiments that required similar reconceptualization[26]. Moreover some first signs indicate that this kind of flexibility can be trained[24].

This re-conceptual flexibility measure is also made up from the series of figures (amongst other series) as displayed above; the measure in fact consists of movies which start for example with the unambiguous figure duck figure on the left and show a slow morph to the rabbit on the right via the ambiguous intermediates. Participant's task is to indicate as soon as possible where they think the movie is heading to, and their flexibility-score is inversely related to the speed of discovery of the alternative.

The third project, supervised by Jellema (PI3, Hull, United Kingdom) will make use of this re-conceptual flexibility measure (and other, newly designed, ones) but will this time to focus on the capacity to re-conceive in autism. In the normal population there is already a wide range in the ability to switch concepts[26]. One specific goal of this project is to investigate to what extent the degree of flexibility in concept-switching in the normal population is correlated with the degree to which people possess autistic-like traits. To this end, not only mild (Asperger) and severe autistic people will be studied, but also typical people selected on the basis of their scores on the Autistic Quotient (AQ) questionnaire[27]. That is, people with AQ scores falling within the lowest and the highest 10% of the total of scores will be used. In this way this project attempts to close the gap between the normal and the autistic population, which will allow exploring the existence of a continuum in the ability to switch concepts in relation to a continuum in autistic traits. Logically the project can profit from Jellema's earlier experience with researching autistic people[32].

It has been suggested that people suffering from autism suffer from so-called 'weak central coherence'[30]. Central coherence is the ability to pull several strands of information together for higher-level meaning. Individuals with autism thus posses a feeble ability to create such a higher-level meaning which makes them insensitive to perceptual illusions such as the Ebbinghaus illusion that result from the joint perceptual information available. Another example is that people with autism have particular difficulty in perceiving the rectangle that results from placing two squares next to each other[5]. Now remember that this was exactly what Kekule did when dismissing two strings (snakes) in favor of one (benzene) ring. Also Verstijnen (PL) has remarked earlier on the fact that this kind of integration of concepts into a new concept at the cost of the earlier ones is one of the most severe forms of reconceptualization and needs the most support from the environment (and initiates the most sketching behavior)[10]. These findings therefore may suggest that people suffering form autism may have severe difficulty in reconceptualizing.

Apart from establishing clinical levels of inflexibility in general, the project supervised by Jellema (PI3) will make a start in dissecting different domains of reconceptualization. Previous research suggests that autistic people are compromised in their processing of biologically-relevant stimuli such as the other's gaze direction and facial expressions. Interestingly so, it has been suggested that they are differently sensitive to animate (biologically defined) and inanimate (culturally defined) figures. Hence, their flexibility to re-conceive may depend on the animate or inanimate character of the figures, which idea will be tested. Because the re-conceptual flexibility measure consists of separate series of inanimate and animate figures this idea can be tested, also new series of morphs from inanimate to animate objects (and vice versa) within a series will be created to this end.

As described above, the three contributing partners will study the same issues with similar material but will stress different aspects of it with different techniques and within different domains. Of course, these different approaches need to be regularly integrated in order to get the general picture. Moreover, the fact that each partner will approach the issue from his/her own domain and will apply his/her own techniques is not to say that there is no overlap in expertise at all: Johan Wagemans for example currently participates in autism research[38,42] and will therefore be a helpful advisor on the PhD project supervised by Tjeerd Jellema, while Ilse Verstijnen has the necessary background in artificial intelligence needed to support Johan Wagemans' Post-Doc researcher. Therefore, both in order to frequently discuss recent results as well as to profit from each other's knowledge and expertise in puzzling out new routes to take, we envision arranging meetings every four months.

a) IP aims and objectives

The first project, supervised by Verstijnen (Utrecht, The Netherlands), will focus on (in)flexibility of mental imagination, its sketching counterpart and their influence on perceptual re-conception. More specifically, experiments need to be carried out in which subjects are asked to think of (imagine) a particular concept (concept A) and then have to categorize a visually presented ambiguous figure, this in order to investigate the influence of 'mind-set' (expectancy) on perception of alternatives. Preliminary experiments along these lines[22] have shown both facilitation and inhibition of pre-conception on re-conception of this figure, depending on the individuals tested and the timing and embedding of the preceding conception. These results need to be extended and to be related to (proficiency in) sketching and re-conceptual flexibility.

The specific objectives are to gain an understanding of

- the interplay of processes contributing to the steering of object recognition away from the ordinary
- the specific influence of high-level processes (conceptual history/expectancy) on reconceptualization
- the specific influence of low-level perceptual history on the perception of alternatives
- individual differences in reconceptualization (re-conceptual flexibility)
- the relationship between reconceptualization and paper-and-pencil sketching

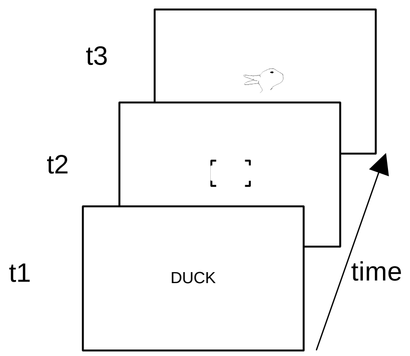
In order to achieve these objectives, we will need to adjust existing object-recognition paradigms to include mental imagery and develop new experimental paradigms.

b) Methodologies/experiments

We recently carried out experiments with ambiguous figures as targets preceded by imagined or perceptual unambiguous primes[22]. The results confirm the earlier findings with perceptual primes and show that also with imagined primes facilitation and inhibition of a perceptual target occur and depend on the duration of the imagined prime. However, the pattern that is found for imagery does not mimic the perceptual pattern in any way; short priming causes interference in imagery but facilitation in perception, while the reverse pattern was found with longer priming durations. The PhD project will start out by elaborating on these results found by the PL.

IP-1.1. Extension of findings of early inhibitory effects of imagining through varying physical overlap

In the experiments shortly described above we applied an adjusted version of a classical priming paradigm. In such a paradigm, a prime precedes an object to be categorized. Next to perceptual primes we also investigated the influence of imagined primes. Before the experiment subjects studied the unambiguous figures such as an unambiguous duck or rabbit (without knowledge of the intervening figures) until they are able to perfectly draw the picture. Before the experiment they also learned to associate the figures with their names (duck or rabbit), this way they will know which figure to imagine during the experiment. During the experiment we controlled for the size and location of the image by asking the subjects to imagine the prime figure (e.g. duck) within size-indicators corresponding with the size of the target. The experiment is schematically laid out below. Note that at t2 (second event) also a real duck figure could occur as a perceptual prime.



In these previous experiments specific care was taken to assure that the exact physical configuration of the imagined prime maximally overlapped with the target. This was done in order to create a baseline. The PhD project will deviate from this approach not only to mimic more natural conditions, but also to create experimental conditions that will allow for a disentanglement of higher and lower order influences on reconceptualization.

The PhD-student's first task will be to hallmark this finding by tuning in on the exact dynamics by varying several parameters within the paradigm. To this end a variety of approaches will be taken:
The exact physical configuration will be varied to vary in the physical overlap of the prime and target. These include simple size transformations for starters, location transformation, and rotations *(1a)*. Hereafter, local deformations on category relevant (e.g. the duck's snout) and irrelevant areas of the figures will be applied *(1b).* And finally, the PhD student has to investigate primes that although learned as being a duck are in fact pictures tending a bit to the rabbit side, such as Figure B displayed above *(1c).* Within *sub-projects 1a, 1b* and *1c* we thus reduce the physical overlap while categorically the figure stays the same (a duck) and investigate the influence of inhibitory effects on conceptualization. Note that these variations as well as those discussed below can mostly be applied to the primes as well as the targets. Moreover duration of primes as well as targets may be varied in all the experiments discussed here, and each participant in the experiments will be tested with the flexibility measure.

IP-1.2. Extension of findings of early inhibitory effects of imagining through varying categorical overlap
Next the PhD will try various forms of disentanglement of the priming picture from its semantic connotation. The PhD will experiment with subjects who learned to associate particular pictures by uninformative labels such as "picture A" for the Duck figure *(2a)*. Or learn an informative but 'wrong' label such as Duck for Figure E displayed above *(2b)*. This way the physical overlap stays constant but the categorical overlap can be varied.

IP-1.3. Extension of findings of early inhibitory effects of imagining through simultaneously varying physical and categorical overlap
The PhD should integrate the findings of the previous sub-projects with experiments that include both physical and semantic changes to the pictures. New pictures will have to be constructed that combine features of duck and rabbits at the same time but are learned by the subjects as either of the two categorizations *(3a)*. This subproject directly relates to the part-based priming studies by De Winter and Wagemans[43,44], and the extension of this project as proposed by Wagemans, IP2, in particular sub-project IP-2.3 on page 29.

Yet another approach allows for a simultaneous variation of physical and categorical overlap. Note that within the Verstijnen & Wagemans series displayed above each individual figure can be identified as either being a duck or being a rabbit (except for the extreme unambiguous figures A and G). Tjeerd Jellema, IP3, has created a second series of morphing figures based on Snodgrass and Vanderwart[47] in which the intervening figures are *not* interpretable as either of the two extremes (see page 29). In other words, the 40%-60% figure is not bi-stable and will not be categorized as a crocodile or an airplane when presented in isolation. By comparing the effects of intervening figures (e.g. 40%-60%) from this latter series with the effects of similarly imbalanced figures from the Verstijnen & Wagemans series[41], the PhD may get a deeper understanding of the role of categorization *(3b)*.

IP-1.4. Extension of other findings of inhibitory effects in the literature; Perky's paradigm.
As mentioned in Section A, only a handful of researchers have found imagery and perception to interact negatively, Perky[46] was on of the first to apply a paradigm that includes categorization. The second paradigm to adapt is the early paradigm of Perky . Perky showed that perception could influence imagery negatively. For example, subjects were asked to imagine a maple leave while looking at a blank screen. Next an elm leaf gradually appeared on this screen. Subjects then found themselves imagining an elm leaf while they had been trying for a maple leaf. All subjects continued to believe they were just imaging an elm leaf, even to a point were the elm leaf was clearly visible. The first obvious adaptation would be to have subjects imagine the Duck figure (for example) and present them with a gradually appearing rabbit figure (figures D through G presented above) *(2a)*. Then to present a slow gradually appearing morph from this duck into the rabbit *(2b)*. And finally to present not only a morph from duck to rabbit but also a morph backwards from rabbit to duck, to investigate whether hysteresis occurs (i.e. the persistence of a percept despite parameter change to values favoring an alternative pattern[45]) and how it is influenced by imagining different concepts. Tjeerd Jellema, IP3, will also investigate hysteresis, in his case to research pathological patterns of hysteresis. The same morphs will be used in this morphing study too[47], once again to investigate the influence of identifiability of the intervening figures in a morph series *(2c).* All these experiments require continuous monitoring of the subject's ongoing categorizations and will be measured with an adjustable slide indicating how 'far off' subjects are from the figure they intended to imagine.

IP-1.5. Extension of / elaboration on previous findings

Since this is the last sub-project we would like the PhD to elaborate on earlier findings within the project. This may for example include further investigation into differential effects found between animate and inanimate stimuli in the previous sub-projects. Or the PhD may engage in researching other avenues that seem promising and are suggested by other projects within the CRP, such as can imagery be of influence on the interrupted presentation paradigm as applied by Wagemans' postdoc, for example what happens when the intervening blanks are 'filled in' by mental images of the kind that are studied or created above. Particularly the figures made for the part-based priming studies may be interesting as intervening mental images. These figures and the imbalanced morph figures (such as Figure B above) may also be applied in imagery experiments to see whether they invite spontaneous sketching behavior to a more or lesser extent. For example, does (im)balance of the an imagined figure relate to the urge to externalize through sketching? In short, the PhD will engage in researching the most pressing research questions that figure at the end of the CRP project.

c) Work plan

IP-1.1	12m	01/09/06 – 31/08/07 (incl. initial background reading)
IP-1.2	9m	01/09/07 – 31/05/08
IP-1.3	9m	01/06/08 – 31/02/09
IP-1.4	9m	01/03/03 – 30/11/09
IP-1.5	9m	01/12/09 – 31/08/10 (incl. finishing PhD thesis)

d) Deliverables and/or milestones

This IP aims at unravelling the influence of preconceptions on reconceptualization. If the results turn out to be publishable each subproject may lead to one or several reports, which will be submitted to an international, peer-reviewed journal of high standards. Less satisfactory results or results that are otherwise unpublishable will be written down in internal reports at the end of a sub-project.

e) Justification for budget items, especially staff costs and equipment.

The PhD will need one upscale computer, a superior CRT monitor, and software licenses (Presentation, E-prime) to carry out the proposed research program. Moreover, a large number of subjects will be needed to participate in the program. Although the University of Utrecht recently introduced a course-credit system for students to participate in experiments, this system turns out be insufficient. In short, most of the subjects will therefore only partake in the experiments in return for financial rewards, usually up to 10 euro per hour. Since most of the experiments will need an average of 15 subjects and will require these subjects to learn the stimuli by head at home and engage them for about two hours per experiment in the laboratory, these experiments (including the pilot experiments) can become costly.

References

43. De Winter, J., & Wagemans, J. (2005). Segmentation of object outlines into parts: A large-scale, integrative study. *Cognition*, in press.
44. De Winter, J., & Wagemans, J. (2006). *Part priming of object naming*. Manuscript submitted.
45. Hock, H. S., Kelso, J. A. S., Schöner, G. (1993). Bistability and hysteresis in the perceptual organization of apparent motion. *Journal of Experimental Psychology: Human Perception and Performance*, 19, 63-80.
46. Perky, C.W. (1910). An Experimental Study of Imagination. *American Journal of Psychology,* 21, 422-452.
47. Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 174-215.

1 - Individual Project contribution to the CRP

a) IP aims and objectives

The overall goal of this IP is to contribute to the understanding of the way in which perception of external information contributes to (re)conceptualization. The focus is on ambiguous figures because they bring the perceiver's contribution to perception/conception to the foreground: The same stimulus can be perceived/conceived differently from time to time and from person to person. The proposed research program consists of a series of intertwined systematic studies, combining experimentation with healthy volunteers and computational modeling. The specific objectives are to understand:

- the natural dynamics of switching as a function of stimulus and person variables
- how intermittent presentation prevents or delays switching
- the interplay between low-level and high-level cues to figure-ground organization and switching
- when and how preceding presentations affect the interpretation of ambiguous figures
- when high-level categorization affects low-level perceptual processing.

In order to achieve these goals, we will develop the necessary experimental paradigms and perform a sufficient number of parametric studies and control experiments. Moreover, we will extend our model to be able to run the necessary simulations as a means to pinpoint the effects to particular processing stages or their interactions.

b) Methodologies/experiments

We have developed a computational model for figure-ground organization and switching between alternative organizations[50], based on an earlier model for subjective contours[48,49]. The model starts from a local signaling of convex and concave borderline segments by means of junction detectors. Based on local occlusion cues relative depth values are assigned at each location along the contour. These are then integrated to determine the depth value of each surface half, one at each side of the borderline, assigning one as figure (i.e., the owner of the edge) and one as background. To introduce the necessary stochastic components, random numbers (drawn from a normal distribution) were multiplied to the local junction signals. In addition, top-down feedback and adaptation were included to settle into a stable interpretation and to switch to an alternative interpretation, respectively. Top-down feedback is implemented as follows: Once the higher level determines which side is figure and which is background, the local responses consistent with this interpretation are enhanced and those that are inconsistent are suppressed. Recent empirical studies have shown that a stable interpretation is maintained longer (and a switch to an alternative interpretation is thus postponed), when stimulus presentation is not continuous but interrupted by a short blank period[16,20]. To be able to simulate the effects of this intermittent presentation, our model needed to incorporate recovery from adaptation during the intervals in which the current interpretation is not seen (i.e., blank period and alternative interpretation). In other words, the adaptation and the recovery mechanisms are not image (input) dependent but interpretation (output) dependent. This strongly suggests that these mechanisms have to reside at higher levels of the visual system. Because our model also includes local (low-level) input mechanisms, it is ideally suited to study further the interplay between low-level and high-level processing mechanisms.

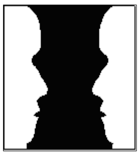
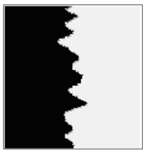
<u>IP-2.1. Parametric studies of the dynamics of switching and how intermittent presentation prevents switching</u>

In this subproject we will investigate the natural dynamics of switching as a function of stimulus and person variables. We will test the idea that the degree of switching partly depends on local cues to ambiguity (e.g., convex versus concave features picked up by the local junction detectors and local occlusion cues) processed at the initial stages before the system is settled into a stable interpretation. In other words, we believe that the image sometimes invites further exploration because triggers to ambiguity are available at preconscious stages. We will also examine whether individuals differ in the degree of switching. In previous research on multistable dot patterns[12,18,19], we noticed that the strength of perceptual grouping decays as an exponential function of distance with a different exponent for different individuals. If the proximity-based attraction is weaker, grouping appears less stable, more ambiguous, and hence switching becomes more likely. In other words, if proximity-based attraction, which appears a hardwired factor, differs between individuals, it is quite likely to assume that individuals also differ in the degree of multistability in figure-ground organization determined by many more factors than just proximity.

We will also investigate the effects of different kinds of intermittent presentation on the degree of switching. For example, we will systematically chart the effects of early versus late interruptions, short versus long interruptions, frequent versus infrequent interruptions, all in combination with different base rate levels of switching (in the presence of continuous presentation). The big advantage of our biologically plausible and computationally specific model is that we can simulate the psychophysical effects and pinpoint their cause at a specific layer of processing or interactions between them.

IP-2.2. Low-level and high-level cues to figure-ground organization and switching

The traditional example of figure-ground bistability, the vase-faces stimulus[58], presents a case of switching between seeing the central part (i.e., the vase) as figure and seeing the two peripheral parts (i.e., the faces) as figure (see Figure IP-2a). So far, our model has been tested only with simpler stimuli, consisting of a central borderline and two sides that both can be seen as figures (see Figure IP-2b). In principle, nothing prevents us to include figural cues in the one-contour case (see Figure IP-2c) as well as in the two-contours case (see Figure IP-2d). The latter two stimulus examples have been used by Peterson et al.[57] to examine the influence of object recognition on figure-ground organization: In Figure IP-2c, seeing the black part as figure becomes more likely (because it represents a wrench), whereas in Figure IP-2d, seeing the white parts as figures becomes more likely (because they represent seahorses).

a  b  c  d 

We will extend our model to be able to incorporate such top-down effects. In the present version of the model, top-down feedback is already included (see above) but it does not favor existing object profiles. This could be added simply as a list of known objects acting as a prior in the process of triggering a stable interpretation from the local image cues. In addition, we will investigate in detail how low-level stimulus features interact with high-level figural properties by creating matched stimuli with similar local features (same profile of convexities and concavities) and by testing upside-down presentations (reducing recognizability in many cases). Furthermore, we will examine whether one-contour versions such as in Figure IP-2b and c are inherently more bistable (because both sides are equally probable on a priori grounds) than two-contours versions such as in Figure IP-2a and d (because a central figure may be more likely on a priori grounds than two peripheral figures).

We have a set-up available for stereoscopic stimulus presentation consisting of an optic bench with two CRT orthogonal monitors, two half-silvered mirrors oriented at 45°, and a chin-rest to position the viewer's eyes. With this set-up we can add stereo disparity cues so that we can present parts of a stimulus at different depth planes. For example, we can present the white part in Figure IP-2c and the black part in Figure IP-2d as being closer to the viewer. In this way, we can induce a power-play between bottom-up disparity cues favoring one interpretation and top-down figural cues favoring another interpretation. Again, this provides nice opportunities for psychophysical experiments as well as computational simulations.

IP-2.3. Extension to other ambiguous figures

In order to facilitate the extrapolation of our findings with the bistable figure-ground stimuli studied in our subprojects IP-2.1 and IP-2.2 to the projects of our colleagues in IP-1 and IP-3, we will also study switching between two rivalry interpretations in the classes of stimuli introduced by Verstijnen and Wagemans[41]. In these stimuli (such as the duck-rabbit shown in Figure IP-1.1a to g), the two rivalry interpretations are two figural interpretations of the same line drawing, which is different from our multistable figure-ground stimuli in which edge assignment rather than figural interpretation plays the key role. We will study the degree of switching at different levels of ambiguity determined by the different morph levels (see Figure IP-1.1) and we will also test whether intermittent interpretation prevents switching to the same extent as in the previously studied bistable figure-ground stimuli.

Using these figural stimuli has the great advantage of being able to prime one of both interpretations by briefly presenting features or parts that are diagnostic for that interpretation. For example, as a part prime for the duck interpretation (see Figure IP-1a) one could present the duck's beak (the two parts facing left), whereas the alternative rabbit interpretation (see Figure IP-1g) could be primed by briefly flashing the rabbit's snout (the upper and lower lips facing right). Intermediate parts (e.g., upper part of the head and the eye at central position) could be used as neutral baseline parts. It is also worth testing whether the ambiguous versions could be made to switch one way or the other by presenting more or less disambiguated parts (e.g., left part more like beak or ears). In previous research aimed at testing part-based object recognition[44], we were able to demonstrate that target objects preceded by briefly presented parts (i.e., 34 ms), validated as perceptually salient parts in an independent study[43] were identified faster than in control conditions where they were presented by other contour fragments of the same object or by parts of another object. In the present project, we will use this part-priming as a tool to influence figural interpretation of ambiguous figures at different levels of ambiguity. The nice aspect of this part-priming procedure is that it may work unconsciously, during the perceptual processes building up a particular interpretation: In our previous study, many subjects were unaware that a prime had been presented and they were never able to identify the object's part or the whole object on the basis of the part only.

IP-2.4. Variations on intermittent presentation

In this subproject we will investigate what kinds of interruptions of the normally continuous stimulus presentation affect the degree of switching. As outlined above, the standard finding in research by Leopold et al.[16] was that interruptions by short blanks were sufficient to maintain the currently prevailing interpretation and hence to reduce the likelihood of switches. We wonder whether interruptions by other than blank stimuli also lead to this suppressed switching behavior. More specifically, we plan to use briefly flashed low-level features (e.g., convex versus concave edge segments), intermediate-level parts, and whole figural regions (possibly also stereoscopically disambiguated ones) to influence the degree of switching. Once we have finished subproject IP-2.3, we can perform these experiments with the whole range of ambiguous stimuli, from simple figure-ground stimuli without figural interpretations (see Figure IP-2b), over figure-ground stimuli with figural interpretations (see Figure IP-2a, c, d), to ambiguous figures with two competing figural interpretations (see Figure IP-1.1). The priming perspective and the intermittent presentation perspective clearly lead to opposite sets of predictions. Psychophysical experiments will tell us which one is right and our model simulations will reveal why.

IP-2.5. Corroboration of direct, subjective measures by indirect, objective measures

For all of the preceding subprojects, it seems important to establish that the subjective measurement of asking subjects what they see and asking them to indicate that a switch between rivalry interpretations has occurred, is reliable and valid. To this end, we will try to develop a more objective but indirect measurement technique. Our current idea is to use a symmetry detection task. Symmetry is a strong and salient regularity, which is easy to detect by the human visual system[60,61]. Subjects would be looking at a single-contour stimulus presented centrally (e.g., Figure IP-2b). After a while (long enough to establish edge assignment and hence figure-ground organization) the contour's symmetric counterpart would be flashed briefly at one side of the image (e.g., left) and a somewhat similar but random contour would be flashed at the opposite side (e.g., right). The hypothesis is that subjects will be better and faster at detecting the symmetry of the two contours (in this case at the left side) when the subject had spontaneously organized the display with the left side as being the figure. This hypothesis is founded on an extensive literature in support of object-based attention[59]. We are currently exploring symmetry detection in interaction with figure-ground organization and objectness[51]. If such an advantage in terms of symmetry detection performance (i.e., fewer errors and shorter response times) were to be found for clearly unambiguous figure-ground stimuli, the size of this advantage could be used as an indirect, objective measure of the subject's spontaneous figure-ground organization (without asking for it directly).

IP-2.6. Categorization effects on shape perception

In all of the preceding subprojects, we study the interplay between low-level and high-level mechanisms on figure-ground organization and figural interpretation. That is, we want to understand to what extent these mechanisms determine the categorical perception of left versus right figure (e.g., Figure IP-2b and c), central figure versus peripheral figures (e.g., Figure IP-2a and d), or one figure versus the other (e.g., duck versus rabbit in Figure IP-1.1). In the final subproject of IP-2 we want to study the reverse effect. That is, we want to understand to what extent the categorical perception determines the low-level perception of the shapes involved. We have previously shown that learned category boundaries enhance the perception of shape differences at the category boundary, making similar physical stimulus differences perceptually more salient when they have become more relevant for the categorization[53]. However, this categorization effect was found only for category boundaries on salient, nameable (so-called separable) shape dimensions like aspect ratio and curvature, not at less salient, non-nameable (so-called integral) shape dimensions (e.g., amplitude and frequency of Fourier descriptors). Similar effects were obtained in macaque monkeys[53,54], ruling out that naming has anything to do with it and making it more likely that we are dealing with a basic perceptual effect.

In on-going work, we are investigating similar issues with meaningful instead of random shapes, using morphs between exemplars of the same basic-level category. For example, we are creating a set of birds by the pair-wise morphing of four different, rather prototypical birds (derived from a larger set of birds[52], an we are imposing either a horizontal or a vertical boundary within this 2 x 2 shape space of birds[56]. The first results indicate that previously found categorization effects on shape perception do not occur (or are rather small) in this within-category shape set. If this null-finding were due to the rather arbitrary category bounds for within-category shapes, it is worth testing whether categorization effects on shape perception can be found with the between-category morphs derived from the stimuli by Verstijnen and Wagemans[26]. In particular, we will test whether the shape difference between a 60%-40% morph and a 40%-60% morph is perceived as bigger than between a 60%-40% morph and an 80%-20% morph, when the pair straddles a category boundary (e.g., switch between duck and rabbit interpretation) than when it does not. As in the related projects IP-1 and IP-3, we can perform these tests for categorical changes within the same superordinate category (e.g., animate vs. inanimate) or across. Again, such top-down effects will then be implemented in the extended version of the computational model.

c) Work plan

IP-2.1	6m	01/09/06 – 28/02/07
IP-2.2	6m	01/03/07 – 31/08/07
IP-2.3	6m	01/09/07 – 28/02/08
IP-2.4	9m	01/03/08 – 31/08/08
IP-2.5	3m	01/09/08 – 30/11/08
IP-2.6	6m	01/12/08 – 31/05/09

d) Deliverables and/or milestones

Each subproject will lead to a report (at the end of the planned time period), which should be submitted to an international, peer-reviewed journal of high standards, if the results are worth publishing (otherwise, they remain internal reports). That is, for some subprojects the promise is only to try to find certain effects to the best of our abilities; there is no guarantee to obtain a particular outcome. For example, we promise to try to find an indirect, objective correlate of figure-ground assignment, as an alternative to asking people what they see but we cannot guarantee that such a side-effect is strong and reliable enough to be used as a fine-grained experimental tool. Likewise, we are not certain that interpreted ambiguous figures will have categorical effects on perceived shape differences. The more risky subprojects are scheduled near the end of the project so that we can always continue with the more fruitful earlier subprojects as an alternative to an unanticipated dead-end. If the research program as a whole has been fruitful enough to inspire an extensive and detailed theory/model of multistable figure-ground organization, we will also try to publish a longer, more integrative paper or book chapter.

e) Justification for budget items, especially staff costs and equipment.

A postdoc is required because of the unique combination of modeling and experimental skills. Two upscale computers (one for modelling, one for experimentation), an excellent CRT (for graphics), and software licenses (Matlab, Eprime) are essential to be able to carry out the proposed research program.

References

48. Kogo, N., Strecha, C., Caenen, G., Wagemans, J., & Van Gool, L. (2002). Reconstruction of subjective surfaces from occlusion cues. In H. H. Bülthoff, S.-W. Lee, T. A. Poggio, & C. Wallraven (Eds.), *Lecture Notes in Computer Science: BMCV 2002 Proceedings* (pp. 311-321). Berlin, Germany: Springer Verlag.
49. Kogo, N., Strecha, C., Van Gool, L., & Wagemans, J. (2006a). Subjective surface reconstruction from occlusion cues: A new approach to model Kanizsa illusory figures. *Psychological Review*. Under revision.
50. Kogo, N., Van Gool, L., & Wagemans, J. (2006b). *Switching dynamics of border ownership: A stochastic model for multistable perception*. Manuscript in preparation.
51. Koning, A., & Wagemans, J. (2005). *Detection of object-based regularities*. Manuscript submitted.
52. Op de Beeck, H., & Wagemans, J. (2001). Visual object categorization at distinct levels of abstraction: A new stimulus set. *Perception, 30,* 1337-1361.
53. Op de Beeck, H., Wagemans, J., & Vogels, R. (2001). Macaque inferotemporal neurons represent low-dimensional configurations of parameterized shapes. *Nature Neuroscience, 4,* 1244-1252.
54. Op de Beeck, H., Wagemans, J., & Vogels, R. (2003a). The effect of category learning on the representation of shape: Dimensions can be biased, but not differentiated. *Journal of Experimental Psychology: General, 132,* 491-511.
55. Op de Beeck, H., Wagemans, J., & Vogels, R. (2003b). Asymmetries in stimulus comparisons by monkey and man. *Current Biology, 13,* 1803-1808.
56. Panis, S., Vangeneugden, J., & Wagemans, J. (2006). *Perceptual representation of within-category similarity of everyday objects*. Manuscript in preparation.
57. Peterson, M. A., de Gelder, B., Rapcsak, S. Z., Gerhardstein, P. C., & Bachoud-Lévi, A.-C. (2000). Object memory effects on figure assignment: Conscious object recognition is not necessary or sufficient. *Vision Research, 40,* 1549-1567.
58. Rubin, E. (1921). *Visuell wahrgenommene figuren*. Copenhagen, Denmark: Glyldendals.
59. Scholl, B. J. (2001). Objects and attention: The state of the art. *Cognition, 80,* 1-46.
60. Wagemans, J. (1997). Characteristics and models of human symmetry detection. *Trends in Cognitive Sciences, 1,* 346-352.
61. Wagemans, J. (1999). Toward a better approach to goodness. *Psychological Review, 106,* 610-621.

1 - Individual Project contribution to the CRP.

a) IP aims and objectives

This project aims to explore individual limitations in the mental and perceptual ability to switch concepts or to form conceptions. A specific aim is to investigate a possible correlation between the degree of flexibility in concept-switching in the normal population and the degree to which people possess autistic-like traits. To this end, not only mild (Asperger) and severe autistic people will be studied, but also typical people selected on the basis of their scores on the Autistic Quotient Questionnaire. As such this project attempts to close the gap between the normal and the autistic population, which will allow us to explore the existence of a continuum in the ability to switch concepts in relation to a continuum in autistic traits. Another aim is to find out whether an impairment in concept switching in autism is a general feature that applies equally well to all categories of concepts, or whether there are categories that are more affected than others. We will specifically test concepts of living, animated objects, versus those of non-living objects, to try and define the concept-switching ability at a more detailed level. Last but not least, insight in variations in the development of the concept-switching ability in these neurologically differentiated subpopulations (autistic versus non-autistic people) will shed light on its neuronal underpinnings.
In the normal, non-patient, population already large differences exist in the ability to form re-conceptions26 suggesting that each normal individual occupies a position on an underlying continuum, ranging from very poor to very adept at concept- switching. We hypothesize that individuals possessing the neuro-developmental condition of autism[79,75] occupy a position on the extreme 'poor' end of this continuum.

What is the evidence for impaired concept-switching in autism? There is a wealth of experimental evidence showing that switching of behavioral patterns is impaired in autism; these patterns are typically rigid and repetitive[33,75]. In fact, repetitive behavioral patterns are considered one of the three core deficits of the autistic syndrome, next to impaired communication/imagination and restricted interests[79]. In contrast, relatively few studies have been devoted to switching of mental concepts in autism. There is, however, ample anecdotal evidence from teachers and caretakers working with autistic people suggesting that the inflexibility also exists at the cognitive level[75]. There is further behavioral and neurobiological evidence that the forming of concepts of living objects, and the processing of the social cues derived from these living objects, is especially (or selectively) impaired in autism[76].

If autistic people are indeed impaired in concept switching, especially with respect to living objects, how would that fit in with existing theories of autism? Various suggestions as to the causes of autism have been put forward[76]. An influential avenue toward the understanding of especially the social deficits of autism is the Theory of Mind (ToM) approach[74,65], which assumes that the autistic mind has difficulties in forming a theory about others' minds, i.e. difficulties in attributing feelings and mental states (such as beliefs and desires) to others. To put it simply, autistic people don't understand people, but often excel in understanding mechanical devices and machines. The idea of impaired concept-switching ties in very well with the ToM model. To understand another agent's mind one needs to be able to switch mental concepts rapidly, because the other agent's mental states, intentions and feelings also change rapidly. Social understanding often involves some sort of hypothesis testing: one forms an idea about e.g. the other's intention and then tests this idea, i.e. one looks for further evidence that will either corroborate or falsify it. This process clearly requires one to be a flexible in re-conceptualization. The inability to do so may be one reason why for autistic people it is impossible to keep up with the pace of social exchanges.

b) Methodologies/experiments

IP-3.1. Testing the concept-switching ability in the normal population in relation to autistic-like traits.
To maximize the range of the concept-switching ability, we will not only compare autistic people to typical people, but we will also divide the normal population into subgroups with maximally differing autistic-like traits. The latter will be achieved by using the AQ (Autistic Quotient) questionnaire[27]. The AQ questionnaire measures autistic-like traits in typical people on the assumption that autism is not an all-or-nothing phenomenon but a continuum, ranging from hardly autistic at all to heavily autistic. Subpopulations of the normal population with the highest and lowest 10% of the total range of AQ scores will be used. The AQ measure has been shown to be able to successfully discriminate between subgroups of the normal population in reflexive orienting tasks, where observing a face with averted eyes results in a (covert) reflexive shift of attention to the gazed-at location[69,70]. AQ scores correlated negatively with the ability of typical people to orient reflexively to such social cues. The emphasis on a maximally wide range of abilities will also be applied to the autistic population, where we will include both high-functioning autistic people (Aspergers) and people diagnosed with classical autism.

IP-3.2. Testing the concept-switching ability in the normal population in relation to an underlying systemizing-empathising dimension.

In contrast to the human mind, the workings of machines (e.g. computers) follow logical rules, and therefore the outcome of each processing stage is in principle predictable. Understanding machines does not require the unpredictable switching of mental concepts, and autistic people typically communicate with, and understand, machines better than humans. This dichotomy between the understanding of humans and machines is reflected in the *Extreme Male Brain Theory* of autism[66]. This theory states that the systemizing-empathizing dimension provides a useful divide between male and female abilities, in that males typically outperform females on systemizing tasks, while females outperform males on empathizing task. The autistic brain is thought to occupy the extreme systemizing (male) end on this dimension, because it excels in systemizing and is very poor in empathizing. The typical male brain can do both tasks yet systemizes better than it empathizes. Indeed, males are about four times more likely to develop autism than females, which fits nicely with the extreme male brain model. The Systemizing Quotient questionnaire (SQ[67]), designed to determine an individual's position on the systemizing-empathizing dimension, will be used. In addition, the usefulness of a related measure, i.e. the Empathizing Quotient (EQ[66]) will be explored.

IP-3.3. Testing concept-switching for living versus non-living objects.

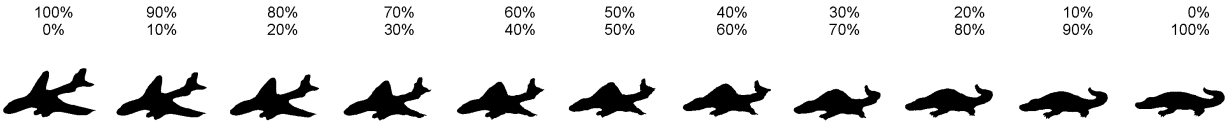
The systemizing-empathizing (or machine-human) dichotomy stresses the importance of the distinction between living and non-living objects. The crucial difference for the current study is that living objects, and especially humans, display a variety of conscious mental states, whereas non-living objects don't. Autistic people have been shown to be compromised in the processing of biologically-relevant stimuli and social cues, conveyed by living agents[30,76]. These stimuli and cues include gaze direction, direction of attention, facial expressions, intentions and goal-directed actions. Therefore, an important aim is to find out whether an impairment in concept switching in autism is a general feature that applies equally well to all categories of objects, or whether there are object categories that are more susceptible than others. Again, ample anecdotal behavioral evidence suggests that autistic people have especially difficulties in dealing with living, animated objects, while non-living objects are dealt with relatively normally. Autistic children have often been reported to treat others (e.g. their caretakers) as if they were objects, rather than living human beings. An autistic child at a crowded beach wanting to go towards the sea may simply step on the bodies of sunbathing people that happen to lie in her path to the sea[75]. We will therefore contrast living to non-living objects in our tests, and hypothesize that the forming of concepts of living objects will be preferentially impaired.

IP-3.4. Comparison of the neurological underpinnings of the concept-switch ability in normal and autistic people.

By including participant groups with differential neurological development, i.e. normal and autistic people, we aim to link a deficit in concept-switching ability to abnormalities in neurological functioning and to a neuro-anatomical substrate. Over the last two decades fundamental insights have been obtained regarding the neural substrate and mechanisms underlying the capacity to perceive and understand animated objects in the normal and autistic brain. Their self-propelled actions and 'intentionality' endows animated objects with a special status amongst the entire range of objects that surround us. It is not surprising therefore that the brain contains areas specialized for the processing of animated objects, as indicated by single cell studies in the primate brain, imaging studies of the human brain, and studies of developmental disorders[62,64,76]. Together these areas comprise the so called 'social brain'[28,29]. Single cell studies in the monkey brain have been particularly influential by stressing the importance of the superior temporal sulcus (STS) in analyzing visual cues derived from the body and its actions, suggesting a specific role for the STS in the perception and understanding of animated objects and their actions[32,78]. Imaging studies in humans confirmed this role for the STS[64]. Interestingly, these studies also showed that the motions of non-living objects (such as tools, e.g. a pair of scissors opening and closing) activated a different area in the temporal lobe (the middle temporal gyrus and the inferior temporal sulcus) than the living objects[71]. These areas are therefore likely candidates for the forming of concepts of animated and non-animated objects, respectively.

Stimuli *(IP-3.1 through IP-3.4)*. Suitable objects will be selected from a large set of contour drawings of a wide range of objects (living and non-living objects) for which normative identification rates have been established by De Winter & Wagemans[72], which in turn was based on the standard set of line drawings by Snodgrass & Vanderwart[47]. In addition, objects will be selected from a stimulus set made by Downing et al.[73]. It is also envisaged that new objects will be drawn and scanned.

Morphs (i.e. interpolations) between pairs of objects will be made using Sqirlz-Morph software (Xiberpix). Basically three types of object pairs will be selected for morphing: (1) Living object to living object, (2) Non-living object to Non-living object, (3) Living object to Non-living object. The number of interpolations will be varied as required: 20 interpolations may be used for presentation of images in discrete steps of 5% change, and several hundreds of interpolations to present the stimuli as short (about 5 s) film clips.



Example of a morphing sequence of a plane (far left) and a crocodile (far right) in steps of 10% change. Note that the object consisting of 50% plane and 50% crocodile, exactly midway the sequence, can not be identified as either of them. Stimulus presentation and data collection will be done using E-prime.

Participants *(IP-3.1 through IP-3.4).* Undergraduate students from Hull University, and adolescents and adults diagnosed as either Asperger or Autistic, will be used. The latter will be recruited through the Clinical Neuroscience Centre at Hull University (Prof. A. Venneri and Dr. M. Shanks). Autistic children will be tested at Northcott Special Needs School in Hull. A feasibility study has been performed on a small group of classical autistic children at Northcott School in Hull. Despite their severe autistic symptoms, these children were well able to perform the test in terms of attention span and ability to verbalize the answers.

Experimental paradigms *(IP-3.1 through IP-3.4).*There will be two basic experimental paradigms, which form the backbone for a number of experiments:
In paradigm 1, the morphing sequences start with an object consisting of 100% object A (and 0% object B). The participant will name this object (which will be easy). As the sequence develops, the influence of object B increases and that of object A decreases until 100% object B (and 0% object A) is reached. We measure the point in the sequence at which the participant correctly names the newly formed object. In this paradigm the participant thus starts off with a specific mental concept in mind, and a reconceptualization needs to take place. The forming of this new concept will be hampered by the existence of the current concept, called perceptual hysteresis (i.e. the persistence of a percept despite parameter change to values favoring an alternative pattern[45]).

In paradigm 2, the sequence starts with an unidentifiable object consisting of 50% object A and 50% object B, i.e. midway the sequence. For the participant, this object has a completely arbitrary form. The object then morphs into either A or B. The participant thus starts off without a concept in mind, and gradually will develop one. In paradigm 2 hysteresis does not play role, and we expect effects to be determined by the nature of the concepts (living vs non-living), while in paradigm 1 both factors can play a role.

We hypothesize that there will be a large variability in the extent of hysteresis, with an progressive increase in hysteresis from the low AQ group, via the high AQ group, to the Aspergers and ending with the highest level of hysteresis in the autistic group. We further hypothesize that on top of the hysteresis effect, there will be an effect for the living vs non-living nature of the objects, such that for the autistic groups detection times will be longer when object B is living (and human) than when non-living, while for the normal groups the reverse will be found (or no difference).

Further experiments, building on the above paradigms, in relation to IP-1 we will investigate priming effects, i.e. to what extent does the e.g. semantic category the first object belongs to determine the speed with which the second object is correctly identified. By gradually shortening the presentation duration of each frame (and increasing the number of interpolations) at a certain point the illusion of motion will occur (apparent motion). This might well affect re-conceptualization[45]. We will also replace the living and non-living objects by morphed sequences of a human face that starts as male and changes into female, and vice versa (in collaboration with Prof David Perrett, St. Andrews, UK[78]), to further study hysteresis for biologically-significant objects.

c) Work plan

IP-3.1	6m	01/09/06 – 28/02/07	Plus stimulus preparation and pilot studies on typical people.
IP-3.2	6m	01/03/07 – 31/08/07	Selecting the most appropriate measures to subdivide the normal population (AQ, SQ, EQ). Selecting Asperger and autistic participants.
IP-3.3	12m	01/09/07 – 31/08/08	Large scale experiments testing both experimental paradigms on all groups. Additional experiments involving priming effects, apparent motion and male/female faces.
IP-3.4	12m	01/09/08 – 31/08/09	Plus writing up PhD thesis.

d) Deliverables and/or milestones

Deliverables: The studies on concept-switching and concept-forming (employing both experimental paradigms), using living and non-living objects for all 4 participants groups (low-AQ, high-AQ, Asperger and autistic), are expected to result in 3-4 papers in international, peer-reviewed journals of high standard. This is the relatively safe part of the IP in terms of publishable results. The additional studies on priming, apparent motion and male/female faces are more risky, but the aim is to publish these as well. If any of these additional studies turns out to be not publishable, then it will remain an internal report. All studies will be presented at conferences.

Milestones: To establish that (1) A continuum exists for the ability to switch concepts and to conceptualize within the normal population. (2) The Autistic Quotient score is negatively correlated with the concept-switching ability, with classical autism being represented on the extreme 'poor' end, and the low-AQ group on the extreme high-ability end, of the concept-switching continuum. (3) The conceptual representations of living and non-living objects are distinct, and that the autistic mind has a specific problem with the concept of living objects. (4) To build a model for the concept-switching ability on the basis of (i) the existence of an underlying continuum, (ii) the known neuroanatomical deficiencies in autism, and (iii) the differential representations of concepts for living and non-living objects. On a more speculative note, we hope our results will contribute to the discovery of a link between deficiencies in (re-)conceptualization in the autistic mind and neurological mechanisms and/or a neuro-anatomical substrate.

e) Justification for budget items, especially staff costs and equipment.

PhD student will do the bulk of the experimental work and writing of manuscripts, liaise with the Hull Clinical neuroscience Centre, the Schools and the NHS. The technician (1 day per week) will assist in making the morphed stimuli. Making these morphs is a laborious, time-consuming job, which would leave the PhD student not enough time for his/her normal duties (programming, experimentation, data analysis, manuscript preparation, and participant management). In addition, the technician will help to organize and manage the normal and autistic participant pools.

References

62. Adolphs, R. (1999). Social cognition and the human brain. *Trends in Cognitive Sciences*, 3, 469-479.
63. Adolphs, R. (2003) The Neurobiology of social cognition. *Current Opinion in Neurobiology*, 11, 231-239.
64. Allison T., Puce A., & McCarthy, G. (2000). Social perception from visual cues: role of the STS region. *Trends in Cognitive Sciences*, 4, 267-278.
65. Baron-Cohen, S. (1995). *Mindblindness: An essay on autism and Theory of Mind*. MIT Press.
66. Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences*, 6, 248-254.
67. Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Weelwright, S. (2003). The systemising quotient (SQ): An investigation of adults with Asperger syndrome or high functioning autism and normal sex differences. *Philosophical Transactions of the Royal Society of London: Series B.*, 358, 361-374.
68. Baron-Cohen, S., & Wheelwright, S. (2004). The Empathy Quotient: An investigation of adults with Asperger syndrome or high functioning autism, and normal sex differences. *Journal of Autism and Developmental Disorders*, 34, 163-175.
69. Bayliss, A. P. & Tipper, S. P. (2005). Gaze and arrow cueing of attention reveals individual differences along the autism spectrum as a function of target context. *British Journal of Psychology*, 96, 1-21.
70. Bayliss, A. P., Di Pelligrino, G., & Tipper, S. P. (2005). Sex differences in eye gaze and symbolic cueing of attention. *The Quaterly Journal of Experimental Psychology*, 58.
71. Beauchamp, M. S., Lee, K. E., Haxby, J. V. & Martin, N. (2003). fMRI responses to video and point-light displays of moving humans and manipulable objects. *Journal of Cognitive Neuroscience*, 15, 991-1001.
72. De Winter, J., & Wagemans, J. (2004). Contour-based object identification and segmentation: Stimuli, norms and data, and software tools. *Behavior Research Methods Instruments & Computers*, 36, 604-624.
73. Downing, P. E., Bray, D., Rogers, J., & Childs, C. (2004). Bodies capture attention when nothing is expected. *Cognition*, 93, B27-B38.
74. Frith, U., Morton, J., & Leslie, A. M. (1991). The cognitive basis of a biological disorder autism. *Trends in Neurosciences*, 14, 433-438.
75. Frith, U. (1995). *Autism: Explaining the Enigma*. Oxford: Blackwell.
76. Frith, U. (2001). Mind blindness and the brain in autism. *Neuron*, 32, 969-979.
77. Jellema, T. & Perrett, D. I. (2002). Coding of visible and hidden objects. Common mechanisms in Perception and Action. *Attention and Performance*, 19, 356-380.
78. Perrett, D. I., & May, K. (1994). Facial shape and judgements of female actractiveness. *Nature*, 368: 239-242.
79. Wing, L. (1988). The Autistic Continuum. In: L. Wing (Ed.), *Aspects of Autism: Biological Research*. London: Gaskell/Royal College of Psychiatrists.