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LABORATORY NOTES

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The northernmost Cognitive Science Laboratory

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Introduction

The University of Tromsø is situated in the town of Tromsø in Norway (69.4°N) and it is the world's northernmost university. Hence, the Cognitive Science Laboratory of the Department of Psychology at the University of Tromsø is also the world's northernmost laboratory of its kind. The University of Tromsø is the fourth and most recent university to be established in Norway. The department of Psychology is also relatively "young" (being established in 1983) and a rather international group of researchers and teachers have formed or currently form our departmental staff. Collectively, our academic backgrounds originate from various universities in Norway as well as from Belgium, Britain, Canada, Chile, Finland, France, Germany, Italy, the Netherlands, Sweden, and the USA.

Among the various parallel projects that are currently run in the cognitive science laboratory, some do take advantage of the geographical location of the university by dealing with the effect of "extreme" latitudes and unusual seasonal patterns of daylight on cognitive and perceptual processing (e.g., Brennen et al. 1999; Brennen 2001). However, our interests, taken collectively, span a rather wide range of topics revolving around key questions in cognitive science, like attention (and its disorders: spatial neglect, ADHD), memory, visual imagery, perception of objects and faces, comprehension and learning, and the organization of knowledge. Moreover, a range of methods are currently used to address the above themes, e.g., studies of brain-damaged patients, eye-tracking, computational modeling, human operant conditioning, and classic cognitive/behavioral methods.

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The cerebral basis of spatial vision

One large project focuses on the cerebral basis of human spatial vision and seeks to obtain converging evidence for a specific theory of two independent spatial encoding subsystems (for a review see Laeng et al. 2003a). The theory assumes that there are alternative and qualitatively different spatial perceptions: one is based on coordinate relations (e.g., the distance between two locations) which occur within a "metric" space and is suitable not only for visual perception and memory but also for the control of movement of the body and its parts (e.g., the distance between the hand and the fork; or the napkin on one's lap and the food on one's silk blouse). In contrast, the other is based on categorical relations, which are abstract (e.g., an object or object's part is 'to the left of', or 'attached to', another object or part) and is most useful in solving problems of object recognition that require the integration of visual information about shape with spatial information about the arrangement of the object's parts (e.g., consider a cat's tail; or a crazed calico cat chasing its own tail). Bruno Laeng (1994) first localized, in a study of a large cohort of brain-damaged patients, "categorical" and "coordinate" spatial functions to the parietal lobes of the left and right hemispheres (LH, RH), respectively. Subsequent research has extended this work to the assessment of lateralization for spatial function in normal subjects (e.g., students), accomplished by use of the divided-fields technique. What we have found is additional support for a "division of labor" between the two hemispheres for such spatial functions, which has, in turn, led us to develop some counterintuitive predictions on the role of each hemisphere in the recognition of different classes of objects. For example, Laeng et al. (1999) showed that the left hemisphere (LH) is superior to the right hemisphere (RH) in recognizing images of contorted poses of flexible objects (e.g., animals, like a cat, seen "curled up"). Moreover, it was found that those subjects who had stronger lateralization

of categorical spatial function to the LH also showed a greater LH advantage in the recognition of such contorted shapes. This evidence supports the view that categorical spatial relations play a role in the "structural descriptions" of objects (i.e., objects' representations based on parts-and-relations; as posited, for example, by David Marr or Irving Biederman) as well as the hypothesis that parts-based descriptions are more relevant to representing the geometry of non-rigid objects than of rigid objects (e.g., artifacts like chairs, drinking glasses, etc.). A study performed on groups of brain-damaged patients (Laeng et al. 2002c) has brought converging evidence to the idea that areas of the LH play an important role in the recognition of objects with flexible geometry, whereas homologous areas of the RH are more apt to recognizing objects with rigid geometry or rigid spatial transformations of all shapes. Finally, in another divided-fields study, Laeng et al. (2003b) have shown that the two hemispheres' complementary roles in either abstract (categorical) or detailed (metric) perceptual relations also underlie a LH superiority in basic-level recognition (e.g., a "cat") and a RH superiority in subordinate-level recognition (e.g., a "Siamese") (as assessed in a picture-name verification task).

Spatial frameworks and disorders of attention

A series of studies have focused on a single case (AE) with a RH stroke resulting in severe neglect. In one study (Laeng et al. 2002b), we showed the co-existence of neglect within different spatial frames: (1) in left hemispace and (2) in 'far' versus 'near' space, both as defined from the patient's viewpoint, as well as (3) for the left side of an object (as defined from an object-centred view). In the experiment, AE's latencies to name the color of two cubes, each located in one hemispace, were measured. In some conditions, the cubes were placed on a table, but in other conditions each cube was held in one hand of an experimenter who could either face the patient or show the cubes while her back was turned towards him. In another condition, the cubes could be positioned either near to (i.e. within reaching distance) or far from the patient (i.e., several meters out of reach), by moving the table or the experimenter. Finally, in some conditions, AE looked at the cubes in a mirror that was positioned far away from his body (because external objects seen in a mirror can be 'near' the patient's body, the patient actually looked at a 'far' location to see an object that is 'near'). The experiment confirmed the presence of all forms of neglect, including object-centred neglect, since not only did AE name the color of a cube seen in his left hemispace more slowly than in his right hemispace, but also latencies increased for a cube held by the experimenter in her left hand and in left hemispace (see also Laeng and Brennen 2003).

In another study of the same patient (Laeng et al. 2002a), we observed that AE severely neglected a single visual target that was present in half of the trials and appeared in variable and unpredictable positions on the computer screen, yet his RTs to targets reported incorrectly as absent were faster than correct rejections and even right-sided hits. AE's fast "neglect" responses seem to indicate that the target was detected but that he remained unaware of its presence. Counterintuitively, his fast misses got faster as the discriminability of the target decreased. One key finding was that fast responses to neglected targets occurred only in a simple feature search task and not in a complex features (conjunction) task. We interpreted these findings as indicating that AE's pre-attentive processing could detect pop-out targets on the left-hand side, but that the attentional search was faulty and aborted early. Hence, the patient's attentional system had an "early start" when "pop out" forms were present, but failed to "grab" the detected target; consequently, by not attending to a stimulus, the patient remained unaware of its presence and quickly responded "no" to present targets.

Category-specific effects in object identification

One project by Torstein Låg illustrates how healthy individuals can be a source of data for evaluating previous research and existing explanations of deficits in brain-damaged patients. A central topic in the last couple of decades has been the study of patients with category-specific deficits in object identification: why do some patients lose their knowledge of, and their ability to recognize, certain categories of objects while apparently retaining this knowledge and ability for other categories? Specifically, Låg (2004) focused on some methodological aspects of category specificity, taking care to use a new set of well-balanced stimuli, so as to avoid the influence of several nuisance variables on each of the probed classes. Then, in a series of experiments involving the naming of pictures, it was found that a category-specific *disadvantage* for natural objects compared to artefacts in normals could be reversed into a category-specific *advantage* for natural objects compared to artefacts. Dramatic changes in the advantages/disadvantages were observed, despite using the same stimuli, when simply manipulating some of the basic parameters of the tasks. For example, when the presentation time of visual stimuli in a naming task was long (1.000 ms), naming was faster for artefacts than for natural objects; instead, with brief presentations (20 ms), the artefact's advantage disappeared entirely.

Eye fixations on human faces

Our laboratory is also equipped with an eye-tracker (built by SMI©) which allows us to measure with precision the eyes' scan paths and fixations. One current project has focused on the analysis of fixations on regions of the human face during tasks where normal subjects are requested to make quick decisions about

various properties of faces (e.g., their sex, their age, etc.). In one study, Line Saether and colleagues explored which parts of the face observers overtly attend to during a sex-judgment task. According to one current hypothesis, the nose is a crucial feature in the accurate assignment of sex to an individual's face. We examined (Saether et al. 2003) this hypothesis by use of the eye-tracker on the assumption that eye fixations help reveal which parts of the face receive greater perceptual analysis than others and, consequently, which parts could be the most diagnostic. Crucially, face-stimuli were presented in four different angles of rotation across the picture plane, from full frontal (0°) to 22.5, 45, and 90° (profile), and each trial was preceded by a fixation point in one of the corners of the screen so as to prevent the confounding of fixations in the centre of the image. Remarkably, the results revealed that the external parts of the face (e.g., hair, chin, ears) received a negligible amount of fixations whereas the nose and the eyes accounted for practically all of the fixations. These results support the view that the human nose plays a significant role in sex judgments.

Eye fixations during mental imagery

One study by Laeng and Teodorescu (2002) addressed a long-standing question concerning mental imagery: are eye movements during visual imagery epiphenomenal or do they actually assist the process of image generation? If the latter were true, commands to the eyes for each fixation could be stored along with the visual representation and then used as a spatial index in a motor-based coordinate system for the proper arrangement of parts of an image. In two experiments, conducted in our laboratory overlooking the Arctic Ocean, subjects viewed an irregular checkerboard or color pictures of fish and were subsequently asked to form mental images of these stimuli while keeping their eyes open. It was found that the percentage of time spent fixating a specific location during perception was highly correlated with the time spent on the same (empty) locations during imagery. The order of scanning of these locations during imagery was also correlated to the original order during perception. Finally, the strength of relatedness of these scan paths and the vividness of each image predicted performance accuracy. Hence, eye scan paths during visual imagery re-enact those of perception of the same visual scene and they play a functional role.

Eye fixations in "change blindness"

A number of recent findings indicate that without focused attention there is no conscious perception. In "change blindness", relatively large changes in a scene can go unnoticed if a brief interruption (e.g., a flicker, a saccade, or an eye-blink) coincides with the change. Under such circumstances, changes are typically not noticed until they are looked directly upon. One ongoing project, led by Morten Øvervoll, seeks to study what is preserved, or lost, across views in change blindness tasks and to what extent unattended stimuli are processed. Using the eye-tracker, temporary changes are initiated whenever an object is fixated. Moreover, several identical objects are presented simultaneously, and by changing various features (e.g., color, form, size, rotation) of the currently fixated object, as compared to the non-fixated objects (which are uniform), we can explore the degree of processing of unattended information.

Eye fixations in attention deficit hyperactivity disorder

Attention deficit hyperactivity disorder (ADHD) is currently defined as a cognitive/behavioral developmental disorder where all clinical criteria are behavioral. Inattentiveness, overactivity, and impulsiveness are presently regarded as the main clinical symptoms. ADHD affects about 5% of primary-school children, mostly boys. Terje Sagvolden and colleagues (Sagvolden et al. 2004) recently proposed a dynamic developmental behavioral theory for ADHD. The theory is based on the hypothesis that altered dopaminergic function plays a pivotal role by failing to modulate non-dopaminergic (primarily glutamate and GABA) signal transmission appropriately. A hypofunctioning mesolimbic dopamine branch produces altered reinforcement of behavior and deficient extinction of previously reinforced behavior. This gives rise to delay aversion, development of hyperactivity in novel situations, impulsiveness, deficient sustained attention, increased behavioral variability, and failure to "inhibit" responses ("disinhibition"). A hypofunctioning mesocortical dopamine branch will cause attention response deficiencies (deficient orienting responses, impaired saccadic eye movements, and poorer attention responses towards a target) and poor behavioral planning (poor executive functions). A hypofunctioning nigrostriatal dopamine branch will cause impaired modulation of motor functions and deficient nondeclarative habit learning and memory. These impairments will give rise to apparent developmental delay, clumsiness, neurological "soft signs", and a "failure to inhibit" responses when quick reactions are required. Hypofunctioning dopamine branches represent the main individual predispositions in the present theory. The theory predicts that behavior and symptoms in ADHD result from the interplay between individual predispositions and the surroundings. The exact ADHD symptoms at a particular time in life will vary and be influenced by factors having positive or negative effects on symptom development. Altered or deficient learning and motor functions will produce special needs for optimal parenting and societal styles. Medication will to some degree normalize the underlying dopamine dysfunction and reduce the special needs of these children. The theory describes how individual predispositions interact with these conditions and produce behavioral,

emotional, and cognitive effects that can turn into relatively stable behavioral patterns. Following Michael Posner's account, the prefrontal loop is mainly involved in directing attention and selecting the behavior needed to achieve a given goal in a given situation. It is suggested that a dysfunctioning mesocortical dopamine branch will cause various attention deficiencies such as inefficient orienting responses and abnormal control of eye saccades as well as poorer attention towards the target. These problems will, in a developmental perspective, result in difficulties with controlling behavior and directing actions towards longer-term accomplishments. In studies of human and non-human primates, two cortical areas have been shown to be important for the voluntary control of saccades: the DLPFC (Brodmann's areas 46 and 9) and the frontal eye field (FEF). Because eye movements can be recorded and quantified with much greater precision than many other behaviors, careful analysis of oculomotor function can be used to investigate motor processes in a neuropsychiatric disorder like ADHD. The study of eye movements also allows us to make inferences about brain function based on abnormal eye movements. In a current project (by Terje Sagvolden et al.), ADHD subjects' eye movements are monitored and analyzed during a visual computerized task. We expect to find abnormalities in these subjects, when compared to matched control subjects, in the execution of their movements as well as in maintaining fixation.

Color synaesthesia

The phenomenon of color synaesthesia has recently received renewed interest within cognitive science. However, the topic has been of interest for a long time among some researchers in our group (e.g., Svartdal and Iversen 1989). Recently, Laeng et al. (2004) conducted a single-case study on a synaesthete (PM) who experiences colors when viewing alphanumeric symbols. It was found that PM's visual search for a target differing from distractors by a synaesthetic color feature takes the form of a "pop-out" search. Thus, it would seem that synaesthesia could occur pre-attentively. However, discrepancies between the regression functions of RTs observed in target-present trials and target-absent trials, and the fact that fast RTs occur only within a few degrees of visual angle from fixation, indicate that PM's synaesthesia does not occur pre-attentively but within the focus of attention.

Human operant conditioning

Another large project, conducted by Frode Svartdal, has pursued topics related to human operant conditioning. One set of studies investigated the relationship between verbal and nonverbal contingency control, and demonstrated conditions under which nonverbal contingency control is likely (e.g., Svartdal 1991, 1992, 1995). For example, in the 1995 study we showed that even behavior that is strongly guided by verbalized rules could be modulated by nonverbal contingencies. More recent experiments have focused on the so-called partial reinforcement extinction effect (PREE) and its opposite, the reverse PREE (RPREE). In essence, the PREE implies that responding reinforced intermittently during acquisition will be more resistant to extinction compared to responding that has been continuously reinforced. The RPREE is the opposite effect. The PREE is the more robust effect, but the conditions under which they appear remain controversial. In one study (Svartdal 2000a), we found that both effects could be observed within the same experiment, indicating that the PREE and RPREE may be interdependent rather than contradictory phenomena. Other studies have investigated whether PREE is also reflected in cognitive measures (Svartdal 2000b, 2003), and the answer seems to be no. For example, in one set of experiments we compared behavioral and cognitive measures of extinction persistence. Subjects exposed to contingencies associated with PREE demonstrated this effect behaviorally, but PREE was not observed in subjects' predictions under the same conditions. Since subjects were able to describe their own persistence behavior in retrospective judgments, we concluded that PREE is not well represented cognitively prior to its behavioral manifestation, but it is well represented after that manifestation.

Seductive details and text comprehension

The work in our laboratory also reflects our interest in text comprehension and mechanisms that hinder and enhance the comprehension process. Tove Dahl (in collaboration with Dariush Araï and Rauno Parrila) conducted a series of studies that examined the effects of different types of text adjuncts on the interestingness of texts and readers' memories of a text's main ideas. Textbook producers often seek to enhance texts with photos and examples; that is, they often use seductive details as text adjuncts (entertaining but relatively unimportant examples, such as psychology textbook anecdotes about researchers' private lives or cartoons with punchlines like "You did very well on your IQ test: you're a man of 49 with the intelligence of a man of 53") as text adjuncts. However, a question that begs to be answered is what kinds of photos and examples have the greatest impact on the comprehension and memory of the text's main ideas. From the perspective of cognitive interest theory, readers will find texts more interesting when they understand them. From the perspective of emotional interest theory, seductive details should enhance readers' engagement and therefore positively affect text comprehension. Our own research has focused on the creation and manipulation of texts of different types (from the fields of geography, philosophy, statistics, and history), with different degrees of interestingness (control texts and control texts augmented with text

adjuncts for enhancing interestingness), and including different adjunct types (cognitive adjuncts vs. seductive details in illustration or written text form). Though we are still learning from our results, our first analyses show that the addition of cognitive adjuncts to a text does not necessarily seem to affect readers' immediate recognition or recall of a text's main ideas, nor does the addition of seductive details necessarily affect the interestingness of an overall text. Contrary to the hypothesis that seductive details are distracting to readers, our findings also show that though readers may recognize or recall as many (or more) of a text's seductive details than its main ideas, the number of main ideas recalled need not be affected by their recall of seductive details—either immediately or over time. Thus, the basic interestingness of a text would seem to be key.

More about pictures in learning and cognition

Another project by Susanne Wiking is directed at determining the value of pictures in a range of cognitive tasks (Wiking 2002). Specific topics include: whether there are automatic interference effects from pictures, how pictures sometimes improve recognition of object names to the same extent as words, and some reasons for a lack of usefulness of pictures in the comprehension of scientific materials. Over different kinds of tasks, the benefits of pictures seem to appear more clearly when the tasks involve handling of visuospatial information. Spatial information is particularly useful when something has to be assembled according to instructions. When performance is measured in practice, rather than as verbal declarative knowledge of how the task can be done, the benefits of using pictures for learning can be estimated in new ways. This approach promises to shed some light on the differences in the cognitive processing of text and pictures that should be acknowledged in the design of instructional media.

Cognition and nutrition

Another project of Susanne Wiking (as a cross-disciplinary project in collaboration with Applied Nutrition and Food Chemistry, Lund University, Sweden) investigates the relationship between cognitive functions and the glycaemic index (GI) of meals (Wiking et al. 2002). Memory and attention rely on an adequate supply of glucose to the brain, and in studies of meal frequency lower levels of blood glucose have often been associated with impaired cognitive performance. This project concerns the quality of foods (in terms of GI) rather than the frequency of food supply. Given that a low-GI product (e.g., pasta) results in a moderate and more sustained response in blood-glucose, the low-GI product is assumed to be more beneficial than a high-GI product (e.g., white wheat bread) for cognitive performance in the later phase (2–4 h) after meals. By presenting tasks with high demands on, for example, attention and working memory, the project aims to identify those foods that are functional for human cognition.

Arctic psychology

The above survey shows that the laboratory is productive and dynamic. However, how is it possible to have such a laboratory 300 km north of the Arctic Circle, with no direct sunlight for 2 months in winter, and 2 months in summer when the sun does not set?! A common intuition amongst people who do not live in the Arctic is that during winter one would be depressed, restless, and cognitively impaired. Tim Brennen and colleagues (1999, 2001) attempted to assess the correctness of this idea by testing 100 residents of Tromsø twice on a battery of cognitive tests: once in the winter darkness and once during the midnight sun. Half of the participants were tested first in winter and the other half first in summer. The battery included tests of short-term memory, face recognition, Stroop, word memory, and time estimation. The data showed that, in contrast to others' assumptions, there were few differences between performance in summer and winter. In fact, on a few tests, participants were quicker in winter than in summer. In other words, as we have known for a long time, there is no evidence for a cognitive deficit in winter in our laboratory!

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