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Spatial Discrimination Performance at Levels of Pattern Separation Demand after Global/Local Processing

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Abstract

The pattern separation process, where sensory input is given an individual place in memory without compromising or overwriting older memory representations, is highly sensitive to small changes in input, and as the similarity between items increases so does pattern separation demand (Clelland et al., 2009; Yassa & Stark, 2011). This experiment tested performance on a pattern separation-dependent spatial discrimination task after manipulating participants' processing styles using the NAVON task. The specific hypothesis was that local processing before testing – a detail oriented approach – would benefit discrimination performance for items at a high level of pattern separation demand, since such items only differ from each other on a detail-level. The constructed material successfully reflected three levels of pattern separation demand, but the processing manipulation only showed different effects on performance at a medium level of demand, where it was best following local processing.

Spatial Discrimination Performance at Levels of Pattern Separation Demand after Global/Local Processing

The process of pattern separation, through which similar sensory input is allowed to be stored as distinct memory representations in the brain, is a major part of memory functioning and it has been the topic of many recent studies in fields like neurophysiology and psychology (Lee & Kesner, 2004; Leutgeb et al., 2007; Bakker et al., 2008; Clelland et al., 2009; Toner et al., 2009; Lacy et al., 2011; for reviews, see; Deng et al., 2010; Yassa & Stark, 2011). Linked to adult neurogenesis, pattern separation takes place in the Dentate gyrus of the hippocampus, where computation of patterns of activity caused by sensory input enables successful encoding of new memories. Being able to separate new stimuli from already stored representations mediates learning and avoids overwriting old memories at encoding (for reviews, see Deng et al., 2010; Yassa & Stark, 2011). By this separation of input into unique memory representations, the process contributes to both successful encoding and retrieval – separating new input from already stored representations not only avoids overwriting existing memories but also makes for more precise recognition judgments by enabling identification of new information as new.

Performance on memory tasks that require much of the pattern separation process has previously been measured in both human and rodent experimental groups, but observations surrounding the process' susceptibility to manipulation in humans are scarce. It could therefore be interesting as well as important to examine if memory performance in pattern separation-dependent situations can somehow be influenced. This is the aim of this paper – here, an attempt to influence memory performance by manipulating participants' processing styles in a task with varied degrees of pattern separation demand is made. The hypothesis and prediction of the experiment presented here is that the high sensitivity to fine-scale information connected with the pattern separation process would be most beneficial to recognition performance if matched with a local, detailed oriented processing style.

Pattern separation demand can be described as increasing as the similarity between items increases, making it necessary to actively differentiate between them. In this study similarity is defined by proximity/distance; as the distance between the features of the test items decreases the similarity among them increases, and with it so does the demand for pattern separation. Compared to a global processing style, a local orientation is thus predicted to benefit recognition in high-demand situations the most, since local-level processing is a feature focused affair; successfully recognizing or identifying a stimulus based on featural information has previously been observed to be improved by a local – feature focused – processing orientation (Weston & Perfect, 2005; Perfect et al., 2008). In sum, it is here investigated if pattern separation, manifested through spatial discrimination memory performance, can be affected by the use of different processing orientations. It is hypothesized that increased pattern separation demand entails increased demand for a feature focus – and that a local processing orientation will best help meet these demands.

The Hippocampus – spatial memory and pattern separation

Through both human and animal studies it has over time become clear that the hippocampal formation, located in the medial temporal lobe, plays a key role in memory functioning (reviews; Squire, 1992; Bird & Burgess, 2008) . The hippocampus is especially thought to be involved in spatial cognition and episodic memory, mediating both processes that enable individuals to locate themselves and objects in space, as well as processes such as recollection which involves a high level of awareness of contextual and autobiographical information (Tulving, 1984; O'Keefe & Dostrovsky, 1971; Squire, 1992; Burgess et al., 2002; Broadbent et al., 2004; Bird & Burgess, 2008; Yonelinas et al., 2010). Over time, memory representations are stored across other areas of the brain becoming gradually more and more independent of the hippocampus and eventually consolidated outside of the hippocampal formation (Alvarez & Squire, 1994). During retrieval of these distributed memory representations, activity corresponding to the activity elicited at encoding is reinstated across cortex, a process which is in great extent mediated by the hippocampus (Johnson & Rugg, 2007).

Experiments have shown that the hippocampus is able to provide a spatial map through special "place cells" identified through rodent experiments, showing characteristics that enable individuals to locate themselves in space by integrating their own movements with a constant representation of the environment, a representation that is independent of the direction in which the individual is facing (O'Keefe & Dostrovsky, 1971; Burgess et al., 2002; Bird & Burgess, 2008). Further insights on the hippocampus' spatial memory functions come from both rodent studies and neuropsychological studies on humans. Rats with hippocampal lesions perform significantly worse than controls on spatial memory tasks (Broadbent et al. 2004), and similar behavioral deficits have been observed in humans with hippocampal damage, who after an incidental encoding period were tested on both recall for objects and their locations (Smith & Milner, 1981). It was especially patients with damages to their right temporal lobe structures that displayed impairments in the location-recall task.

Two central functions of the hippocampus, that help mediate both spatial cognition and general recollection, is the pattern completion and pattern separation processes (reviews; Deng et al., 2010; Yassa & Stark, 2011). The ability to retrieve entire memories on the basis of a partial cue is attributed to the pattern completion process in which neuronal activity caused by a cue spreads across networks, eventually managing to activate the entire pattern making up the targeted memory representation. Pattern separation on the other hand works primarily during encoding, making sure that the patterns of activity caused by new input – although maybe similar to previously stored representations – gets stored as separate, unique representations in memory (Deng et al., 2010; Yassa & Stark, 2011). Instead of replacing old memories, new input that causes patterns of activity similar to those already stored, can thus be given their own place in memory. This finely-tuned capacity of detecting differences in patterns of activity is central for encoding, but also helps during retrieval in situations high in pattern separation demand – situations in which the discrimination between an old item and a similar new item is necessary. Naturally, not all new input puts equally high demand on the pattern separation process; sometimes new information is greatly different from anything else previously stored, and the need for comparing and detecting differences between patterns of activity does not even present itself. Pattern separation demand is instead high when the patterns of activity the hippocampus have to process resemble one another.

The process of pattern separation is considered to be dependent on a neural circuit involving input from the entorhinal cortex to the Dentate gyrus (DG), a sub region in the hippocampus that in turn forwards the processed input to another sub region called the CA3 area. The CA3 area also receives information directly from the entorhinal cortex and forwards this combined input on to other sub regions before output in the end of the hippocampal circuit gets projected back to layers of the cortex (Deng et al., 2010; Yassa & Stark, 2011). Information necessary for recall and pattern completion goes directly to the CA3, while information necessary for pattern separation passes through the DG before reaching CA3. Evidence from both animal and human studies imply that the DG is highly sensitive to small changes in input, it displays changed activity corresponding to changed input at a very early stage (Gilbert et al., 2001; Leutgeb et al., 2007; Bakker et al., 2008; Lacy et al., 2011). Dissociations in connection to pattern separation functioning between these two areas, DG and CA3, have been established by several researchers (mostly through animal experiments since methods used with rats allow access to hippocampal sub-regions in a way human experimental techniques do not), and results point at the DG mediating pattern separation together with CA3 which, depending on the input it receives can display both pattern completion and separation characteristics (Lee & Kesner, 2004; Leutgeb et al., 2007; Deng et al., 2001; Yassa & Stark, 2011; Lacy et al., 2011). In 2004, Lee and Kesner established a dissociation between the two areas and demonstrated their involvement in memory encoding and retrieval. Spatial learning, was severely impaired in rats that had lesioned paths of input from the DG to CA3 while memory retrieval was unaffected, suggesting that the information provided from the DG is crucial for pattern separation and encoding. Rats that had intact DG input-paths to CA3, but instead prevented direct input from the entorhinal cortex to CA3 displayed opposite patterns – impaired retrieval performances, but unaffected encoding (Lee & Kesner, 2004). Together, the results provide a picture of the hippocampal areas behind pattern separation and their immediate connection to memory encoding and retrieval.

Pattern separation-dependent memory studies

Performance on tasks requiring pattern separation, in various degrees and settings and for both animals and humans, has been measured in a number of studies (Gilbert et al., 1998; Leutgeb et al., 2007; Bakker et al., 2008; Clelland et al., 2009; McTighe et al., 2009; Talpos et al., 2010; Lacy et al., 2011). One way of exploring pattern separation further has been to compare healthy rats to rats with different types of hippocampal lesions. Behavioral measures most often include some version of a spatial two-choice discrimination task where a target location is separated in various degrees from a distractor location. In one trial rats can encounter a though choice, where the target and distractor locations appear close to each other (demanding much pattern separation), while in another trial the choice could be easier (locations set further apart), i.e. demanding less pattern separation. Compared to healthy rats, lesioned rats perform significantly worse in trials that require much of pattern separation, indicating that pattern separation-dependent spatial memory performance is definitely also hippocampus-dependent (Gilbert et al., 1998; Gilbert et al., 2001; Clelland et al., 2009; McTighe et al., 2009; Talpos et al., 2010).

Two test tasks connected to this spatial discrimination paradigm that yield behavioral data are frequently encountered in the rodent literature on pattern separation. A popular test setting is the Radial-arm Maze (Olton & Samuelson, 1976) where two out of eight arms of the maze are open during testing; one arm is the old arm, presented to the rat before testing, while one arm is the new target arm. The rat has to go down the target arm in order to perform successfully on the task – in some trials the two arms are separated from each other by three closed arms, in some by two and in others by only one closed arm, making it a trial high in pattern separation demand (Gilbert et al., 2001; Clelland et al., 2009). The other type of test task involves training rats to respond to presented items via a touchscreen apparatus; in the study phase of each trial one square-shaped item is illuminated on the screen and in the test phase the item is paired with a second illuminated square. The rat has to discriminate between old and new squares by identifying the new square in order to get rewarded. In some trials the two test squares are presented far apart and in other trials closer together – demanding more pattern separation dependent memory performance (Clelland et al., 2009; McTighe et al., 2009; Creer et al., 2010; Talpos et al., 2010).

When it comes to studies on the human pattern separation ability, methods have been more focused on presenting three different categories of items to participants; old items, (the ones presented in the study phase) new items and lures – material similar to the old items, that should be identified as lures or new items instead of old (Bakker et al., 2008; Toner et al., 2009; Yassa et al., 2011; Lacy et al., 2011). Measuring how participants respond to these lures is thought to provide a picture of their pattern separation ability – their ability to reject a lure instead of accepting it as an old item. Many pattern separation studies with humans have used brain imaging methods like fMRI in order to observe activity related to the different categories of items, for example; Bakker et al. (2008) tested participants while measuring brain activity during an incidental encoding task – if a lure caused activity similar to the activity of new items, it was considered to have been rejected but if it elicited activity patterns similar to those of old items the lure was considered to have been falsely accepted as old, indicating poor pattern separation performance (Bakker et al., 2008).

Neurogenesis and pattern separation

As described above, results from both rodent and human experiments have together provided support for the involvement of the Dentate gyrus and the CA3 areas of the hippocampus in pattern separation (Lee & Kesner, 2004; Leutgeb et al., 2007; for reviews, see; Deng et al., 2010; Yassa & Stark, 2011). Why these areas are able to contribute to pattern separation has also been the subject of many studies. Researchers argue that the answer can be found in the neurogenesis taking place in the Dentate gyrus. Experiments where the DG neurogenesis in rats have been ablated display results indicating that the new adult-born neurons play a central role in pattern separation and memory encoding, and that increased neurogenesis can help improve performance on pattern separation demanding tasks and general spatial memory tasks (Nilsson et al., 1999; Clelland et al., 2009; Deng et al., 2010; Sahay et al., 2011). Newborn neurons most likely help in pattern separation by providing a temporal aspect to the encoding process. Old representations automatically get separable from the patterns of activity caused by new information through the constant availability of new locations in which to store information. Patterns of activity related to new input most likely use cells that were not available at the time of encoding for old representations, which makes it possible to avoid overlapping and overwriting at encoding (Aimone et al., 2006; Deng et al., 2010). Studies have also examined what kind of factors can help increase neurogenesis, for both rats and humans, and in turn memory performance. Results indicate that exercise, as well as living in enriched environments, and also engaging in tasks demanding hippocampal-dependent learning could all help increase neurogenesis (Nilsson et al., 1999; Creer et al., 2010; Erickson et al., 2011, for a review, see Deng et al., 2010). As individuals grow older, their pattern separation abilities weaken (Toner et al., 2009; Stark et al., 2010; Burke et al., 2010; Sahay et al., 2011; Yassa & Stark., 2011). Older human adults show impaired pattern separation abilities compared to younger adults, and often instead display a bias towards pattern completion at the expense of pattern separation (Toner et al., 2009; Stark et al., 2010; Yassa et al., 2011). Similar results have been observed in studies comparing older rats to younger rats (Burke et al., 2010; Sahay et al., 2011).

Neurogenesis in the hippocampus and DG has also been studied in connection to stress and depression, as well as in relation to diseases affecting neural structures and cognitive functioning such as Alzheimers' disease (Jacobs, 2002; Luine et al., 1994; Mirescu & Gould, 2006; Sahay & Hen, 2007; Winner et al., 2011). Findings suggest that stress affects both neurogenesis and spatial memory performance negatively, although behavioral studies on spatial memory and pattern separation in patient groups are few. Sahay et al. (2011) suggest that an impaired pattern separation ability might be involved in various anxiety disorders, promoting an excessive generalization focus in patients, while overly active pattern separation might account for parts of the excessive attention to detail in people with autism (Sahay et al., 2011).

The aim of this study is to extend the knowledge surrounding pattern separation from a behavioral point of view. Measuring participants' performance in a two-choice, pattern separation-dependent discrimination task after manipulating the way in which participants approach the presented stimuli, could provide further insights to the nature of the process and to which factors might affect it. Is it possible to improve discrimination performance at a high level of pattern separation demand by biasing participants towards a local processing orientation? Could a local, detailed focused orientation amplify the detail-sensitivity of pattern separation and thereby memory performance? Results could help paint a bigger picture of what might affect pattern separation, and if evidence of a successful manipulation presents itself it would motivate further trials with various age and patient groups.

Global and local processing as experimental manipulation

A commonly accepted account for how encoding and retrieval processes interact and which factors learning and recognition are best benefitted by is the transfer appropriate processing theory (TAP), it suggests that the value of a certain encoding-strategy is dependent on the nature of the to-be encoded information, as well as the situations in which the retrieval of the information later on most likely will occur (Morris et al., 1977). Retrieval is according to this view also benefitted by corresponding to the way in which the material was encoded. Supported further by insights from research on the cortical reinstatement hypothesis (Johnson & Rugg, 2007), the core of the TAP theory can thus be summarized as stating that the greater the encoding-retrieval circumstance overlap is, the greater the chance for successful memory performance will be. In light of this fundamental principle, studies have used different types of processing – either consistent with the to-be remembered material or inconsistent with it, in order to manipulate participants' memory performances. A period of globally processing manipulation material before the retrieval of holistically perceived information such as faces, has proven beneficial to memory performance, while local processing has been observed to improve recognition for items high in featural information (Macrae & Lewis, 2002; Perfect, 2003; Weston & Perfect, 2005).

Engaging participants in these different processing styles biases them into approaching presented test stimuli with one specific focus; a local, detail-oriented focus or a global holistic focus. This approach-controlling has been observed to bring about effects in participants' performances in a variety of tasks, and most relevant to this study are the effects observed in memory tasks (Macrae & Lewis, 2002; Perfect, 2003; Weston & Perfect, 2005; Perfect et al, 2007). The type of processing engaged in carries over across tasks, influencing performance on the test task by controlling the way in which participants completes it. One paradigm dominates the literature when it comes to using this biasing of processing style as a manipulation variable; the NAVON paradigm. In this section, literature on research involving processing orientations will be reviewed, and the main focus lies on the NAVON paradigm.

The NAVON paradigm

In 1977 David Navon created and presented a set of hierarchical stimuli that aimed at examining the nature of visual perception (Navon, 1977). His theory was that visual scenes are "decomposed", not built up. This implied a temporally organized nature of visual perception – that we start by experiencing the global whole and by a process of decomposition come to experience the parts that make it up. The NAVON-task, that is still very much relevant in psychological research, has since been used as a manipulation-task in studies investigating the effects of processing types on performance at tasks in other areas (Macrae & Lewis, 2002; Perfect, 2003; Large & McMullen, 2006; Borst & Kosslyn, 2010; Bouvet et al, 2011). There are two ways of completing the NAVON task – one that demands focus at the global level of the stimuli and one that demands focus at the local level. The idea behind using the NAVON stimuli as a manipulation task is that the type of processing it forces the participant to partake in will carry over to subsequent experimental tasks, shaping the way in which the participant approaches the presented information and in turn performs on the experimental tests. The hope is thus to put the participant in either a global or a local processing orientation and that the effects of that orientation will be visible in performance on the experimental tasks.

The NAVON task was originally used to demonstrate the hypothesized *global precedence effect*, the idea that global information is processed at an earlier stage than local information (Navon, 1977). In one of his experiments he showed his participants a series of large letters, all made up out of smaller letters. This way, his items included two different levels of information simultaneously – the large letter constituted the global level while the small letters, its featural components, constituted the local level. The two levels could be consistent or inconsistent with each other; the large letters “H” and “S” could both be built up either by several small Hs or Ss, giving Navon two different test conditions. Participants were in the experiment instructed to identify only one of the two levels at a time and results showed what has come to be called a global precedence effect; response times were significantly faster at the global level compared to the local level, suggesting that global information trumps local information in the competition for attention. Also, identifying the local level when letters were incongruent proved to be harder compared to identifying the global level under incongruent circumstances. This was interpreted as a *global interference effect* and taken as evidence for an additional advantage for global information; while performing the task at the local level, inconsistent global information seemed to severely be disturbing participants and impairing their performance. No such observation was made for the global level, suggesting that the global information is inescapable in a way that local information is not (Navon, 1977).

The NAVON effect in recognition memory for faces

Recognition memory for faces is an area that can provide several illustrating examples of how the NAVON task has been used as an instrument of manipulating, inducing, processing orientations (Macrae & Lewis, 2002; Perfect, 2003; Weston & Perfect, 2005; Hills & Lewis, 2007; Hills & Lewis, 2008; Lewis et al. 2009). It could be argued that the NAVON task is now generally considered to be a reliable inducer of global and local processing orientations, and face recognition is probably one of the areas in which the NAVON task has been most frequently used as such a manipulation task.

In 2002, Macrae and Lewis introduced the NAVON task as an alternative to the verbalization manipulation in verbal overshadowing experiments (Schooler & Engstler-Schooler, 1990) and reached results in line with the previous observations – memory performance for faces was significantly impaired after processing the local level of the NAVON letters and improved in the global condition when compared to a control group (Macrae & Lewis, 2002). By using the same test-material as Schooler and Engstler-Schooler did in their original verbal overshadowing study (1990), Macrae and Lewis replicated much of the method choices from the original study, trying to show the same results only having changed the manipulation task from verbalization to the completion of the NAVON task. In the study, a video-tape of a robbery was presented to the participants after which they were asked to complete one of three manipulation tasks; the local level NAVON task, the global level NAVON task or a control task. Participants in the two NAVON conditions gave verbal responses to the experimenter following the presentation of each letter-item for 10 minutes while the control group read out loud from a textbook for 10 minutes. In the following test phase, participants were asked to look at a target-present line-up of simultaneously presented pictures of faces and identify the perpetrator from the video. The analysis revealed a significant NAVON-effect; a negative effect on performance following local processing. Controls showed a success rate at 60% while the local level group showed a much lower success rate at just 30%. The global group was significantly better than both locals and controls at a success rate of 83% (Macrae & Lewis, 2002). In line with the transfer appropriate processing theory, the global processing orientation sustained by the NAVON task in the global condition benefited memory performance for faces – a stimulus processed in a global way, while the local orientation induced and sustained by the NAVON task in the local condition impaired memory performance by breaking the preferred global type of processing.

After presenting these results of the NAVON tasks' effect on face recognition, Macrae and Lewis' report from 2002 inspired a substantial amount of similar studies. In 2003, Perfect presented a study that followed the same line of thought as that of Macrae and Lewis in 2002. Using the same video material he too tested memory performance for faces following the completion of the NAVON task. In contrast to Macrae and Lewis, Perfect let each participant complete both versions of the task before entering the test phase. After seeing the video, one group started doing the NAVON task with the global instructions before switching over to the local instructions while the other group finished the task in the opposite order. The control group read out loud from a text book during the 10 minutes the manipulation groups did their tasks. When asked to identify the perpetrator from the target-present, simultaneously displayed line-up of pictures the control group had a success rate of 70%. The global group (those who started in the local condition and finished in the global condition) performed better at a level of 80% success – although this was not a significant improvement compared to the controls. However, an impairment was observed in the local group (the ones that had started in the global condition and finished in the local condition). Their success rate was only at a level of 43%, significantly worse than the control and global groups' performance (Perfect, 2003).

These results strengthen the ones observed in the study made by Macrae and Lewis, but it also provides a touch of additional information – it seems to be the type of task completed directly prior to the test that influences performance. Having disturbed the positive global process by completing the local version of the task, participants could by completing the global version still find their way back to the preferable global processing orientation. This indicates that it is the shift in orientation and processing style that matters for memory performance in these types of situations, and that the NAVON task can induce these shifts and orientations by involving participants in a specific type of processing – either beneficial or disadvantageous for the purpose of the test task.

The effect over various experimental designs

The two studies above have used almost identical experimental designs, but far from every study on face recognition and processing orientations has done so. One study that failed to see any effects such as those described above was made by Lawson in 2007. She wanted to see if the cross-task bias effect supposedly caused by the NAVON task was as strong as the studies of Macrae & Lewis (2002) and Perfect (2003) implied. She predicted, as the other studies had done, that local processing would disturb the performance for faces while global processing was thought to benefit it. She tested participants with both upright and inverted stimuli in two experiments. In the inverted condition, where global information is disrupted, globally processing the NAVON letters was thought to be disadvantageous for successful recognition. Participants studied the items and then responded to 44 either global or local NAVON letters, the control group did mental arithmetic during the same amount of time. In none of the experiments did the NAVON manipulation give any effects, performance was overall weakest in the inverted condition, but not in any significant connection to the different manipulation conditions.

Lawson, in contrast to Macrae & Lewis (2002) and Perfect (2003), presented her items sequentially in the test phase – opening up for the risk of diminishing the NAVON effect in a way that their simultaneous line-up presentations did not. To compensate for the extra demand put on the NAVON task she included a reinstatement of the effect by presenting three NAVON letters for participants to respond to in between each test item. The observation of the temporal limitations of the effect was also spotted by Hills and Lewis (2007) who reported that the effect had decreased in strength after just 30-60 seconds into the their test phase while measuring recognition for faces with a sequential presentation style. One possible explanation is that the faces presented in the test phase become manipulators of processing orientations themselves – causing the local orientation induced by the local level NAVON task to disappear in favor for a global orientation. In one of Hills and Lewis' (2007) experiments, they too reinstated the effect by letting participants respond to additional NAVON letters. Both studies looked for the NAVON effect in very similar ways, but reached different results. Lawson did not find any sign of performance being influenced by the NAVON task, while Hills and Lewis did. After reinstating the effect by adding NAVON letters to the test phase they reached results that, in line with the previously describes studies, showed that the processing of local level NAVON letters impairs recognition performance for faces.

Although Lawson did not find any evidence of a NAVON effect, it has been observed in several other studies. Comparing a number of test settings to each other, Perfect et al in 2007, found no significant differences between target present and target absent designs, nor between sequential and simultaneous presenting styles at testing – but a general positive effect of global level NAVON was observed in all cases. Accuracy levels were in average almost twice as high in global conditions compared to local; 69% to 33%, and improved in average by 20% compared to control conditions (Perfect et al., 2007). Using the task both during encoding and testing, embedded in between each presented item, and in different combinations over phases has been a way of investigating the effect in a more extensive manner (Weston et al., 2008; Lewis et al., 2009). By letting groups perform different combinations of tasks at encoding and retrieval of faces, Lewis et al. (2009), found that being consistent in processing style over phases gave rise to the best results. This meant that consistent local processing, although worse than consistent global processing, was better than moving from a local processing style at encoding to a global at retrieval.

Additional support for the NAVON effect from the area of face recognition involves the observation of the local level NAVON task being helpful in tasks requiring local processing for successful performance (Weston & Perfect, 2005). If responding to the global level of NAVON letters is helpful to performance in a task that involves global information, the same relationship should exist for local processing as well. Recognition performance, as made evident by data from response times, in a composite face halves task was, in line with this reversed hypothesis, in fact improved after local NAVON processing compared to global NAVON processing, supporting the effect further (Weston & Perfect, 2005).

Similarity and the NAVON effect

Many studies that have used the NAVON material as a manipulation task in order to induce different processing orientations are concerned with face recognition, but there are a few studies outside that field also interested in manipulating orientations using hierarchical material such as the NAVON letters. Here, a few examples more closely related to pattern separation demand are described. One study, relevant to the one presented in this report in regards to the inclusion of degrees of similarity, studied object discrimination after local and global priming (Large & McMullen, 2006). The experimenters predicted that global priming, processing the global level of hierarchical items (in this case digits, not letters), would promote attention to more coarse-scaled information which would be beneficial for object discrimination at a basic category level, and that local priming in a corresponding way would benefit discrimination at a subordinate categorical level by promoting attention to more fine-scaled information. When discriminating between visually similar objects on a subordinate level, local priming made correct discriminations faster compared to global priming. Fastest response times at the basic level for similar objects and at the subordinate level for dissimilar objects followed global priming. Global priming also brought on higher accuracy levels of discrimination at the basic level compared to at the subordinate level, in line with the prediction. Most relevant to the prediction of the present study on pattern separation and processing orientations is the fact that discrimination between visually similar objects at the subordinate categorical level, the level which displayed the overall longest response times, were improved following local priming.

Also in relation to similarity and dissimilarity, a series of experiments made by Förster in 2009 showed that when asked to generate similarities and dissimilarities between two items (e.g. two countries, two TV-shows, two pieces of art), a global processing orientation elicited by the NAVON task increased the number of similarities generated while a local orientation increased the number of dissimilarities generated. When he reversed the order of the experimental tasks, it became evident that the global level of the NAVON task was completed much faster following a phase of generating similarities between two items compared to after generating dissimilarities, and that the reverse was true for the local level of the NAVON task – it was completed much faster after generating dissimilarities compared to similarities (Förster, 2009).

Other observations in relation to the NAVON task is that people in positive moods seem to embrace the processing orientation most accessible at the time, be it the global or local, to a greater extent than people in a negative mood (Huntsinger et al., 2010), and people with Alzheimer’s disease seem to display a local precedence effect instead of the normal global one, as well as troubles in switching between processing the two levels (Slavin et al., 2002).

Behind the NAVON effect I – hemispheric lateralization

We have seen that performance on a variety of tasks can be influenced by biasing participants towards specific types of processing – priming them into using different ways of approaching stimuli, with either a global or local focus. The instrument we have focused on is the NAVON material and the processing of its' global and local levels. But by which mechanism does the biasing/priming operate? What is it that constitutes the processing orientations? Global and local processing, many times in the form of completing the NAVON task, has been researched from the perspective of hemisphere-specific processing (Sergent, 1982; Kosslyn et al., 1994; Delis et al., 1986; Robertson & Delis, 1986; Martinez et al., 1997; Chabris & Kosslyn, 1998; Han et al., 2002; Borst & Kosslyn, 2012; Lee et al., 2012; for a review see, Jager & Postma, 2003). One suggestion based on the findings from this area is that the NAVON task influences performance by priming lateralized hemispheric activity (Borst & Kosslyn, 2010).

The right and left hemispheres of the brain have been observed to play different parts in global and local processing (for a review; Jager & Postma, 2003). Neuropsychological studies have shown that patients with right hemispheric damages are impaired in the global condition of hierarchical stimuli tasks (such as the NAVON task) while patients with damages to the left hemisphere are impaired in the local condition (Delis et al., 1986; Robertson & Delis, 1986). It is suggested that this lateralization is due to the differences in size of the neuronal receptive fields in the hemispheres; the large receptive fields of the right hemisphere corresponds to low resolution output and global information, while the smaller receptive fields of the left hemisphere corresponds to higher resolution output and local information (Sergent, 1992; Kosslyn et al., 1994; Chabris & Kosslyn, 1998; Borst & Kosslyn, 2010; review Jager & Postma, 2003). The low spatial frequency of global stimuli is more efficiently handled by the right hemisphere, and the high spatial frequency of local stimuli is best handled by the left hemisphere.

Categorical and coordinate spatial relations judgments have returned several times in the literature, illustrating both the hemispheric lateralization and NAVON effect

(Chabris & Kosslyn, 1998; Borst & Kosslyn, 2010). Categorical judgments, such as "left, right, above, below", connected to the small receptive fields of the left hemisphere, were made faster following local NAVON processing, while coordinate judgments of distance and location, connected to the larger receptive fields of the right hemisphere, were made faster following global NAVON processing. The suggestion based on these results is that the NAVON task really operates by priming activity in the corresponding hemisphere (Borst & Kosslyn, 2010). Studies have used both linguistic and non-linguistic material (NAVON letters and other hierarchically constructed shapes), as well as verbal and non-verbal response requirements in order to not confound this lateralization with the one connected to language (Boles, 1984; Delis et al., 1986). Consider also the fact that most of the previously reviewed studies have not taken this into account; both Macrae & Lewis (2002), and Perfect (2003) used the linguistic NAVON material and collected verbal responses from their participants.

Both studies using EEG and fMRI methods have observed signs of this type of lateralization (Martinez et al., 1997; Lee et al., 2012), some even pointing at gender differences in response times over global conditions (Lee et al., 2012). Han et al. (2010) proposed that it is in a competition between the hemispheres that the asymmetry occurs. Presenting hierarchical items in either unilateral or central positions of the visual field, a method used in studies on healthy participants, Hans team (2010) came to the conclusion that the asymmetry arose when items had been centrally presented, and attenuated after unilateral presentation. Centrally presented hierarchical information reaches both hemispheres and causes a competition over processing-privileges, which results in the observed asymmetry. The right hemisphere have more resources to win global processing-privileges and the left hemisphere is more likely to win local processing-privileges (Han et al., 2010).

Behind the NAVON effect II – asymmetry of the NAVON letters

An asymmetry over hemispheres for global and local information processing is described above, but there is another type of asymmetry also relevant here. The NAVON letters are hierarchical to their nature, one dimension contains another – when researching how different groups perform on this global/local task, this is not an issue. But when the hierarchical letters are used as an instrument of manipulation, their imbalanced nature might not only bring good things. When comparing two effects by equal criteria, it would help to have induced them on equal terms – instead of having used material biased from the beginning. The global precedence effect and the global interference effect both demonstrate that the global level of the NAVON material has a greater impact on subjects compared to the local level. In order to respond to the local level, you have to pass through the global level – leaving the instrument of inducing a local orientation somewhat tainted by the global information.

Attempts have been made to create material less globally biased, material that includes both global and local information, but levels the playing field at least a bit. Perfect et al., in 2008, used what they called local-precedence NAVON material in addition to the standard global-precedence letters. Their aim was to replicate the studies of Macrae & Lewis (2002) and Weston & Perfect (2005) with both types of NAVON stimuli in order to get more un-biased results. The local-precedence letters were bigger than the original letters, and made up by fewer small letters spaced further apart from each other. The researchers argued that previous studies might have confounded processing orientations with the question of dominance – responding to the global level has meant responding to the dominant level, while responding to the local level has meant responding to the non-dominant level. Perfects' team raises the question if results from processing orientation experiments, up until the use of both types of precedence stimuli, merely are results from a type of inhibition experiments (Perfect et al., 2008).

After observing some interesting results, the researchers proposed a theory of asymmetrical inhibition as a way of explaining the effects brought on by the NAVON material. In conditions using the original, global-precedence material, results were the same as in the original studies; the global response-condition aided face recognition for upright faces at the same time as the local response-condition sped up RT's in the composite face halves task. What was interesting was that the local-precedence material displayed entirely opposite results – displayed positive results even though connected to a "disadvantageous" type of processing. The researchers suggested that it is the inhibition of the dominant level that transfers over tasks, not a specific processing orientation. The two non-dominant levels (the local level in the original global-precedence task and the global level in the local-precedence task), both require inhibition of the dominant level, and this would make them less likely to cause successful performance – this was exactly what the results of Perfect et al. displayed.

The researchers presented an account of asymmetrical inhibition as an explanation, where the automatic processing connected to a congruence between NAVON response-levels and precedence-type is broken and exchanged to a controlled/analytic processing style connected to an incongruence between NAVON response-levels and precedence-type (Perfect et al. 2008).

Summarizing the NAVON task

The NAVON paradigm and studies including the task as experimental manipulation have been given much space in this background section. It has been necessary to review this literature in order to be able to motivate the methodological choices made here, in this spatial discrimination experiment. That repeatedly responding to one of the two levels of the hierarchical NAVON items can cause performance on a variety of tasks to be either impaired or improved has become evident from the examples given above. The original NAVON material gives rise to a global precedence effect as well as a global interference effect – when using it as a manipulation task, this precedence imbalance should perhaps be considered. When using it in the hopes of inducing different processing orientations, it should also be taken into consideration that the effect seems to be temporally limited and in need of reinstatement, especially since some test material (e.g. pictures of faces) risk reversing the manipulation itself. Sometimes the effect becomes visible through accuracy levels, while at other times it is displayed in response times. Hemispheric asymmetry, a lateralization of activity connected to global and local processing, provides one possible explanation to the mechanism behind the effect (Borst & Kosslyn, 2010), which according to Perfect et al. (2008) might have something to do with inhibition and the use of two different types of processing; automatic vs. controlled. Despite the underlying mechanism not being completely clear, the task seems to fulfill its purpose, making it a strong candidate in the choice of inducer for processing orientations/styles.

The prediction in light of the reviewed literature

In short, the hypothesis of this study is specific; it predicts that local processing will benefit spatial discrimination performance on a task high in pattern separation demand, since high pattern separation demand is defined by the need to distinguish amongst items based on featural information. Looking at the reviewed literature, it should be clear that the prediction finds its foundation in results from studies that stresses the importance of transfer appropriate processing – engaging in local processing in connection to the encoding and retrieval of featural information improves memory performance compared to global processing and control tasks (Weston and Perfect, 2005; Perfect et al., 2008).

Method

Design

This experiment followed a 2 x 3 within subjects design with two experimental factors; processing type and pattern separation demand. There were two levels to the factor of processing type, a local level and a global level, while there were three levels of pattern separation demand; high, medium and low. The two processing type levels, local and global, made two separate experimental blocks where memory performance was tested for all three levels of pattern separation demand. The test task was a spatial discrimination task thought to measure memory performance by letting participants discriminate between new and old items in a two-choice test situation.

Participants

Thirty individuals participated in this memory experiment; 10 men and 20 women, with the mean age of 31 (*SD* 11.95). Participants came from different age-groups, professions and geographical areas of Sweden, making this sample diverse in several aspects. Every participant gave written consent prior to the experiment, and was at the completion of their session given an ice-cream voucher as appreciation for their participation. All participants had normal or corrected to normal sight.

Material

The experiment was created and presented through the E-Prime 2.0 software on a Sony Vaio laptop with Windows 7. It consisted of picture material that was separately created in MS Paint. There were two categories of pictures; NAVON material and test material. Pictures in both categories shared fundamental components, namely a square-system backdrop. The NAVON letters and test items (colored squares, further described below) were then added to this constant background. The square-system consisted of 10 x 10 slightly rectangular grey squares (1,6 mm x 1,4 mm) separated by light-grey 1 millimeter thick lines, it measured in total 16,8 cm x 15 cm. Since the item-specific information was added-on within this area, the pictures kept this size at all times. Each picture was framed by a thin white frame and presented on a grey screen. The idea was to create a correspondence between local/global processing and the test material – the size of the global level NAVON letter corresponded in amount of squares to the low condition of separation demand while the local level in the same way corresponded to the high condition of separation demand. Figures 1a. and 1b. below present examples of the material.

NAVON-material

It is possible to divide the NAVON letters used in this experiment into two different categories and two subcategories. First, in contrast to the previously reviewed studies, letters could either be local or global – meaning that they differed in design depending on the instructions given to the participant. Second, at a subordinate level letters could either be consistent or inconsistent; an E could be built up by Es or for example Fs. It was at all times capital letters in 28 point Calibri font that were applied on to the grey square-system. NAVON letters measured six squares high and four squares wide (approximately 5.5 x 8 cm), with one component-letter centered in each square. The component letters measured 5 x 3 mm. The NAVON letters were always presented in the center of the square-system, leaving three empty vertical rows of squares on each side and two horizontal rows at the top and bottom. This was the construction of both local and global letters.

Coloring The difference between local and global letters was that their component-letters were colored in different ways. Global letters were made up by all blue-colored components, making the entire NAVON letter blue. The local letters on the other hand consisted of only one blue component-letter with the remaining components being white. The single blue component of the local letters was created in order to keep the correspondence to the square-system intact without making the task too easy – if it had not mattered which component-letter the participant was supposed to identify, he/she could easily have targeted only one specific letter-square throughout the task, possibly minimizing the locality of it if being able to disregard the rest of the NAVON letter entirely. This spatial uncertainty was thus thought to ensure local processing in the environment of the square-system. Navon used a similar method in his original study from 1977 in order to ensure processing of the entire letters (Navon, 1977).

This coloring also made the number of local letters greater than the number of global letters, although this difference was not noticeable in the experiment, where an equal amount of letters were presented in both blocks. The letters used were: E, F, H, P and U. In the global condition, these letters were represented by one consistent picture and each by two inconsistent pictures; E was made up by F and U, F was made up by E and P, H by P and U, P by F and H, and U by E and H. These combinations were the same in the local condition, even though each consistent and inconsistent letter came in four different versions – the blue component-letter changed location four times for each local NAVON letter; the consistent E could thus appear in one of four ways, and its inconsistent relatives "EF" and "EU" could too.

a.

b.

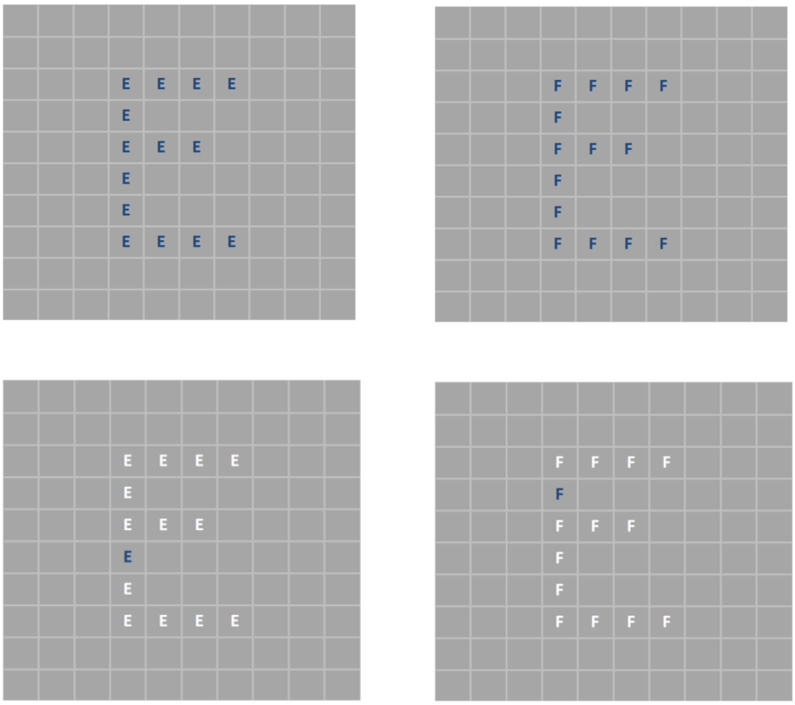

Figure 1. **a.** *Global Congruent and Incongruent Material.* ***b.*** *Local Congruent and Incongruent Material.*

Spatial discrimination test material

The material used in this experiment was inspired by the material and methods of some of the rodent studies reviewed above, that measured memory performance in relation to pattern separation demand by letting rats discriminate between old and new items presented in varying distances from each other on a touchscreen (McTighe et al., 2009; Clelland et al., 2009; Talpos & McTighe, 2010). Although the design and materials have been modified here the basic idea has been kept intact in hopes of providing a simple and straight forward way of measuring memory performance in relation to pattern separation demand.

Coloring Two sets of pictures were created as study and test items. Items in both categories consisted of the grey square-system in which one or two squares, depending on which phase the item belonged to, had been colored with one of six possible colors; green, cerise, orange, purple, turquoise, and yellow. Twelve study items, which included one colored square each, were created for every color; all colors appeared in twelve different squares, making a total of 72 study items. For each study item, a corresponding test item was created, thus making a total of 72 study-test pairs. The test items included two colored squares, one being the original/old square located in the same place as in the corresponding study item, and one new colored square. The use of colors was an attempt to create individual and distinguishable items in order to be able to show a series of items in the study phase and subsequent test phase. By creating separable “characters” the need to only test memory for one item at a time was avoided. The choice of only six returning colors was motivated by the fact that the amount of available colors is limited, together with the fact that a substantial amount of NAVON letters were presented in between trials, minimizing the risk of any confusion.

Positioning The new square in every test item could be positioned in one of three ways; either directly adjacent to the old square, two grey squares away or four grey squares away (never diagonally). These degrees of separation divided items into the three test conditions; high (adjacent), medium (separated by two squares) and low (separated by four squares). Each color was represented by four items in every separation demand condition. New squares could also be positioned in four different directions from the old square (to the right, left, above or below), these directions were evenly distributed across separations and colors. In the end this meant that every response-key on the keyboard was meant to be used the same amount of times – the four directions was represented an equal amount of times, evenly spread across colors and separations. The outer row of squares in the system was never used, it always remained an empty frame in order not to provide participants with the possibility to "anchor" their memory of the colors onto the edges and/or corners of the picture. Thus, of the 10 x 10 square-system, only 8 x 8 squares were active. The active 64 squares all hosted the 72 study item squares, which meant that 8 squares were used twice, although never for the same color.

a.

b.

c.

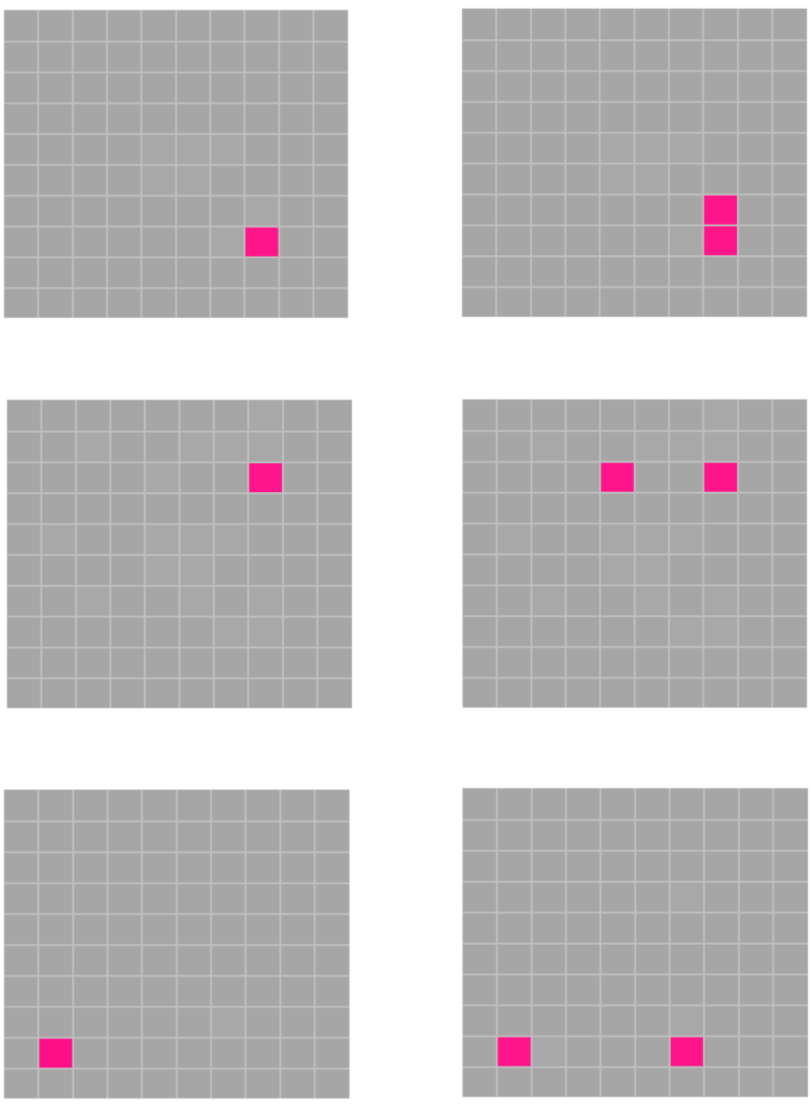

Figure 2. *Spatial Discrimination Study and Test Items.* **a.** *Study-Test Pair in the High Separation Condition,* **b.** *Study-Test Pair in the Medium Separation Condition,* **c.** *Study-Test Pair in the Low Separation Condition.*

Procedure

All participants were tested individually, in various libraries and other calm office-like spaces. Only the experimenter was present together with the participant during the experiment. After being informed about the study and signing a written consent form, the participant was presented with a few example pictures. They displayed the two types of NAVON letters as well as an example of the study and test items. Instructions were given verbally as the participant viewed the example pictures, and also in written form on the computer screen at the beginning of the session. Participants were instructed to provide their responses as correct and fast as possible.

The experiment consisted of two blocks, one local and one global – guided by the nature of the manipulation task, the NAVON letters. The blocks were further divided into 12 trials, each consisting of a sequence of four phases; a NAVON phase where 20 letters were presented, a study-phase where six items (one of each color, two of each separation type) were presented, a second NAVON phase with only 10 letters and a final test phase where the test items paired with the study items were presented. Fixation crosses were always presented for 500 ms in between letters and items. In NAVON phases, participants identified the letter (global/local) by using the keyboard of the computer; all possible answer letter-keys (E, F, H, P and U) were marked with stickers for extra clarity. NAVON letters were presented for a maximum of 4000 ms although an earlier response from the participants controlled the pace in which they followed on each other. Study and test items were presented for 5000 ms each. Every trial and its individual phases were preceded by an etiquette, signaling either that a new trial was starting or which phase would be next. At halftime, when the first block was finished, the written instructions originally displayed returned and the participant started the second block by pressing the space-key. The block-order was counterbalanced across participants so that the possible risk of fatigue would affect both conditions equally. One block took approximately 25 minutes to finish and the entire experimental session was about 50 minutes long. After completing the experiment, participants were informed of the research question in more detail and of the hypotheses of the study.

Study-Test 2 x twelve sets of six items (out of both the study and test material) had been created in order to correspond to the twelve trials of the two experimental blocks. The order of presentation of these sets were randomized across subjects – although individual items were not completely randomized this way, it was a practical strategy adopted in order to make sure the right study-test item-pairs always appeared together in the same trial. This makes it clear that it was the same 72 pairs of items that were used in both blocks, although combined into two different 12-set versions. The material was the same, but the sets the items were included in differed in composition across blocks. Participants were thus tested on the same material twice, with the main difference being the manipulation task in between the study and test phases. The fact that the block-order was counterbalanced across participants should have balanced out any potential effects of this repetition. None of the participants reported any sense of repetition over blocks.

In the study phase, six items were displayed one after another in a sequence. The participants' only task was to memorize the location of the colored square in the square-system. In the test phase, six items paired with the ones from the study phase were displayed in a sequence – here, participants had to identify the old square by signaling its position in relation to the new square, using the arrow keys on the numeric keypad at the far right on the keyboard. As the letters, these keys were also marked with stickers for extra clarity. These arrows (also numbers 2, 4, 6 and 8) signaled if the old target square was "the one to the left/right" or "the one above/below". Items were not presented in the same order in the two phases of a trial – it was not memory for a sequence that was supposed to be measured, so different orders of presentation between study and test were thought to make performance more item-specific.

NAVON As described above, the NAVON task was used two times in every trial; both before encoding and before retrieval. An equal amount of consistent and inconsistent letters were presented in every NAVON phase. The longest sequence was that one prior to encoding in the start of all trials, participants identified 20 letters in this phase. The aim was to ensure that participants were engaged in a sufficient amount of local/global processing at the beginning of each trial. The temporal limitations of the NAVON effect motivated following the recipe of reinstating it (Hills & Lewis, 2007), so a second phase of NAVON was included between study and test phases. This second phase not only reinstated the hoped for NAVON effect with 10 extra letters, but also worked as a distraction task – hopefully eliminating the risk of the recognition performance merely being a result of short term memory/working memory processes.

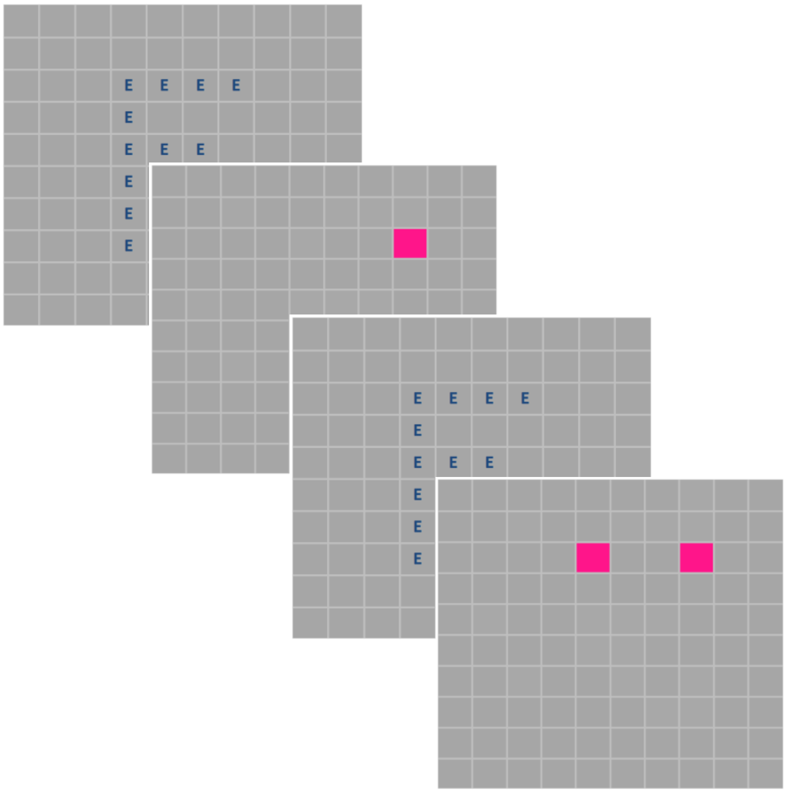

Figure 3. *Trial Procedure. Navon Task, Study Phase, Navon Task, Test Phase.*

Control condition There was no control condition in this experiment, participants all completed both manipulation tasks, but no neutral control task. The decision to not include a third task was based on the unavoidability of global and local processing. A task that would involve neither global nor local processing was hard to imagine, and even though the results will not be able to be compared to a neutral, no-manipulation condition, a potential difference between the two blocks could still be observed. Other studies using the NAVON task and various versions of it have often included control tasks, some have let their participants read a text out loud (Macrae & Lewis, 2002; Perfect, 2003; Perfect et al., 2007), done maze puzzles (Weston & Perfect, 2005), or even processed non-hierarchical "neutral NAVON letters" (Lewis et al., 2009). It could be argued that all of these tasks are not neutral base-line tasks (not just a lack of manipulation) but rather another type of manipulation. Results following global and local processing compared to results following reading is just that – results compared to those observed after reading, not after any kind of "neutral processing".

Looking at the proposed hemispheric lateralization explanation of the NAVON effect (Borst & Kosslyn, 2010; Han et al., 2010), one would have to include a control task that did not prime activity in either of the hemispheres, or in both hemispheres the same amount. Turning to the asymmetrical inhibition proposition (Perfect et al., 2008), the control task should at least not include hierarchical material, allowing for inhibition of one level in favor for another – but all non-hierarchical material do not seem free from being either global or local. Even the one-dimensional "neutral" non-hierarchical letter used as a control task by Lewis et al. (2009) seem considerably more global than local, almost to the same level as the congruent global NAVON letters. The downside of not having a control condition is that the two manipulation conditions can only be compared to one another, but this type of comparison might still be informative. Even though it will not be possible to conclude if one orientation improves or impairs performance relative to a neutral condition, it would be possible to see if one of the two orientations seems more beneficial for memory performance compared to the other. If a difference is observed, all else being equal, it should be connectable with the two types of manipulation.

Results

Presented below are results from two sets of collected data; participants' responses to the NAVON letters and their responses in the spatial discrimination task carrying information about their memory performance during different levels of pattern separation demand. Data from one participant was excluded from both analyses due to missing responses in one entire experimental block, the local half of the experiment. All data was analyzed using Microsoft Office Excel and SPSS Statistics 20 software.

NAVON data

Two types of data from the local and global NAVON tasks were collected; accuracy scores and response times (RT). The NAVON data was analyzed in order to make sure participants had completed the task in the correct way, and that they thus had engaged correctly in the manipulation. Responses from four participants were excluded from further analysis since an initial screening of mean accuracy and RTs revealed that these four participants had systematically responded to the global incongruent letters in the wrong way, leaving them to process half the global block in almost a local fashion. Results presented below are thereby based on data collected from 25 participants. Mean performances between blocks are presented in Table 1.

Accuracy An overview of mean performances over blocks (local and global) and conditions (congruent and incongruent), reveals an overall high level of accuracy. Mean performance was equally high in both local (M = .99) and global (M = .99) blocks, this was not put through any further analysis. Looking at the two congruency conditions it becomes clear that incongruent material (M = .98) was slightly less well identified compared to congruent material (M = .99), as expected. There was no difference between blocks in connection to congruent material (Local M = .99, Global M = .99), but there was a slight difference in accuracy over blocks for incongruent material (Local M = .99, Global M = .98). This imbalance between blocks was analyzed in a paired samples t-test specifically in order to investigate a possible local interference effect for the global material, but the difference was found to be non-significant, $t(24) = -1.40$, p = .175. Since the overall performance indicated ceiling effects, no further statistical analyses were performed.

Response times Besides collecting accuracy data, response times (RTs) were registered and analyzed in a two-way repeated measures ANOVA in order to investigate if there was an interaction effect of processing level (local/global) and congruency (congruent/incongruent) to be found in participants performance. There was a main effect of congruency $F(1, 24) = 75.64$, $p < .0005$, that indicated that congruent material (M = 904.95 ms) was significantly responded to faster than incongruent material (M = 955.06), but no such effect was present for the factor of processing level; $F(1, 24)$ = .858, ns. However, an interaction effect of the two conditions was observed, $F(1, 24)$ = 24.38, $p < .0005$. Paired-samples t-tests revealed that congruent material received the fastest responses compared to incongruent material in both the local ($t(24) = -4.48$, $p < .0005$) and the global block ($t(24) = -8.24$, $p < .0005$). One additional paired-samples t-test was performed in order to specifically compare RTs in relation to incongruent material over blocks and thus see if RTs support any type of interference effect, but there was no difference in RTs between blocks for incongruent material; $t(24) = .90$, p = .38.

Table 1.

Means and Standard Deviations for NAVON Accuracy and Response Times (RTs) in Congruency Conditions (C; Congruent, IC; Incongruent) Over Local and Global Blocks.

		Local		Global	
	Congruency	*M*	*SD*	*M*	*SD*
Accuracy					
	C	.99	.009	.99	.009
	IC	.99	.013	.98	.019
RTs (ms)					
	C	914	197	896	163
	IC	940	199	970	178

In sum, accuracy levels in both blocks were high and no significant difference was observed between them. Congruent material displayed higher accuracy levels than incongruent material over all, but there was no real difference between the two types of material across blocks. Response times paralleled the accuracy data; there was no real difference in response times over blocks, although congruent material was responded to faster compared to incongruent material over all, and significantly so within blocks. Altogether, the data display very high levels of accuracy but does not imply any global/local precedence or interference effects.

Spatial discrimination data

Two types of data, accuracy and response times (RTs), were registered from the spatial discrimination test sections of the experiment. Data from all three separation-demand levels (high, medium, low) was analyzed in order to establish a possible connection to the two different types of NAVON processing, local and global. The aim of the analyses presented in this section was to investigate if memory performance had in some way been affected by the two types of processing engaged in during the manipulation task.

Excluded data The four participants excluded from the NAVON analysis continued to be excluded from further analyzing since comprehension and correct completion of the manipulation task was required. After an initial screening for outliers in both accuracy and RT data, responses from one additional participant was excluded. In total, this made six exclusions. In order to re-balance the sample that by these exclusions had lost more participants that had started in the local block compared to the global block, data from two more participants (the last two global-starters that had been tested) was excluded. Presented below is thus the analyzed data from 22 of the original 30 participants; 7 men and 15 women, with the mean age of 30.6 ($SD = 11.5$). Table 2 provides overviews of the results.

Accuracy A two-way repeated measures ANOVA that included the two factors of NAVON processing and separation demand was performed in order to investigate a possible relationship between discrimination performance in the three separation demand conditions (high, medium and low) and the two processing types (local and global). No such interaction effect of separation demand and processing type was found, $F(2, 20) = 3.28$, ns. The analysis revealed a main effect of separation demand, $F(2, 20) = 22.77$, $p < .0005$, but no such effect for the factor of processing type; $F(1, 21) = .32$, ns, where performance was similar in both local ($M = .79$) and the global ($M = .78$) blocks. Bonferroni corrected post-hoc analysis explored the data in the three separation conditions further, revealing that the high separation demand condition ($M = .70$) significantly differed from both the medium ($M = .82$) and the low ($M = .84$) conditions ($p < .0005$) displaying the lowest accuracy level of all. No significant difference in accuracy existed between the medium and the low conditions ($p = .646$).

A screening of the means generated in the ANOVA, for all three separation demand conditions between blocks, revealed that accuracy means were very similar in the high demand condition over blocks (Local $M = .70$, Global $M = .71$) and relatively similar in the low separation demand condition (Local $M = .83$, Global $M = .85$). Due to the specific nature of the prediction of the study, the between block means were tested further in a series of paired-samples t-tests. These differences for the high and low separation demand conditions did not turned out to be significant when t-tested, testing made it clear that accuracy levels were significantly dissimilar between blocks in the medium separation demand condition (Local $M = .85$, Global $M = .79$), $t(21) = 2.28$, $p = .03$ (two-tailed). One interesting observation that can be made, although only from a mean point of view, is that both the high and the medium conditions display the best performance in the local block, while the opposite is true for the low condition.

Response times Apart from the accuracy data presented above, the response times in separation demand conditions over blocks were also collected and analyzed. The two factors separation demand and processing type were analyzed in a two-way repeated measures ANOVA in order to see if the manipulation of processing type had any influence over RTs in the three separation demand conditions. In accordance with accuracy results, the analysis made it clear that there was no such interaction effect present, $F(2, 20) = .88$, ns. A main effect of separation demand was however observed; $F(2, 20) = 47.08$, $p < .0005$, while no such effect of processing type was significant, $F(1, 21) = .001$, ns. The difference in RTs between the local (*M* = 1851 ms) and the global (M = 1859 ms) blocks was thus, in line with the accuracy data not statistically significant. Bonferroni corrected post-hoc analysis showed that the high separation demand condition had the longest response times (*M* = 2043 ms), followed by the medium condition (*M* = 1786 ms) and lastly by the low condition which displayed the overall fastest RTs (*M* = 1721 ms). All separation demand conditions were in connection to RTs (although not in connection to accuracy levels) significantly distinguishable from each other; the high condition differed from both the medium and low conditions ($p < .0005$), who also differed from each other ($p = .036$).

Looking at the means in the three conditions across blocks, it becomes evident that (as for the accuracy data) the high and medium conditions received faster responses in the local block than in the global block; the high separation demand condition (Local *M* = 2025 ms, Global *M* = 2060 ms) and the medium condition (Local *M* = 1776 ms, Global *M* = 1795 ms). The opposite was however true for the low separation demand condition which displayed the fastest RTs in the global block (Local *M* = 1751 ms, Global *M* = 1690 ms). Although none of these between-block differences were significant, as investigated in a series of paired-samples t-tests in order to follow up the specific prediction of the local blocks' effect on performance in the high demand condition, this general difference in balance mirrors the one observed in the accuracy data.

Table 2.

Means and Standard Deviations for Discrimination Test Accuracy and Response Times (RTs) in Separation Demand Conditions over Local and Global Blocks.

NAVON Blocks		Local		Global		Total
	Separation	*M*	*SD*	*M*	*SD*	*M*
Accuracy	H	.70	.10	.71	.10	.70
	M	.85	.10	.79	.11	.82
	L	.83	.13	.85	.11	.84
RT (ms)	H	2025	535	2060	519	2043
	M	1776	448	1795	466	1786
	L	1751	428	1690	393	1721

In sum, there was no interaction present between the two factors of processing type and separation demand. A main effect for separation demand was present in both accuracy and RT analyses, where the high demand condition proved to be the toughest one followed by the medium condition and lastly the low condition. No real differences between blocks, independent of separation demand, was observed for either set of data. The high and the medium separation demand conditions displayed the best performances (measured in both accuracy and RTs) following local processing, while the low separation demand condition displayed opposite results – however, the between-block difference was only statistically significant for accuracy data in the medium separation demand condition.

Discussion

Interpreting the results

Over all, performance was fairly high on both types of tasks included in the experiment; the NAVON task had accuracy rates in the top 90% in all its four categories (global congruent & incongruent, local congruent & incongruent) and discrimination performance was at its lowest on a mean level of 70% . Making sure that participants had completed the NAVON tasks in the right way was important, since performance in the discrimination task otherwise would have been irrelevant to the question and hypothesis at hand. The hypothesis presented here was that local and global processing would bias participants' way of approaching the presented items during both encoding and retrieval and in turn affect their performances on a task that varied in pattern separation demand. It was especially predicted that a local processing orientation, primed by responding to the local level of the NAVON letters, would be the most beneficial for successful performance at a high level of pattern separation demand.

Accuracy levels did not support this prediction, as performance in the high separation demand condition (as well as performance in the low separation demand condition) remained the same across blocks. The hypothesized interaction effect between pattern separation demand and processing type was thus not observed. However, for one of the three conditions, processing type seem to have had an effect; performance in the medium demand condition was significantly the highest following local processing. One aspect of the results that will be discussed in more detail below is the fact that both accuracy and RT data display a pattern where performance is best following local processing in the high and medium conditions, while the low separation demand condition display the highest means of performance following global processing. But first, a section will be dedicated to the discussion of the results observed in connection to the NAVON task.

NAVON – performance and material

The NAVON material created for this study did not yield the typical results connected to this type of hierarchical stimuli – no global precedence effect, nor any global interference effect can be spotted in the results presented here. This might suggest that the methodological choice of creating two different sets of letters, coloring the global and local letters in different ways, might have taken away some of the global levels' influence over responses to the local letters (while keeping the correspondence to the square-system). Not only is it impossible to infer global precedence and interference effects, it is also impossible to spot local versions of those effects for the global material – a good sign that indicates that this particular construction of the NAVON material did not reduce the global interference effect only to end up creating a local interference effect instead. General performance on the NAVON task did not differ between blocks; neither the local nor the global block displayed higher accuracy levels or RTs compared to one another. This could be interpreted as a good sign, an indication that no imbalance of task difficulty was present. In line with previous observations (Navon, 1977) congruent material was over all responded to faster and with higher accuracy compared to incongruent material. The fact that there were no significant differences between blocks in results connected to incongruent material is what implies the absence of any kind of interference effect.

Trying to understand the results from the two NAVON tasks in relation to the asymmetrical inhibition proposal (Perfect et al., 2008), proves to be a bit problematic here since neither a global nor a local precedence effect was present in participants' responses. In general, this makes it hard to evaluate the results in relation to any theory that assumes some kind of precedence in the material. Since none of the normally observed within-task effects were present, it is hard to match the results of this study to previous NAVON studies in a definite way. Finding another way of ensuring local processing of the letters whilst keeping the connection to the square-system intact (and thus the symmetry between the NAVON task and the discrimination test), would perhaps enable the use of the original, global-precedence, form of NAVON material. This could be the preferred method, it would in the end yield fully comparable NAVON results and possibly even stronger effects for discrimination performance – global precedence material is after all the type of material that in the past have displayed the results that constitutes the premises for the prediction of this study. There is a possibility that global-precedence material might be necessary in order to observe results that are in line with the specific prediction of this study. If there is a chance that such material would amplify the effects of processing on discrimination performance over pattern separation demand conditions, a way to combine it with the square-system without erasing the locality of the local level would be required.

Discrimination performance – separation demand & global/local processing

Analyses of accuracy and response times for discrimination performance made it clear that the hypothesis and prediction did not get enough support from the collected data. Participants performed in similar ways over both blocks, independently of separation demand conditions – neither accuracy levels or RTs were significantly separable from each other between blocks. The first thing worth mentioning is the performance between separation demand conditions (independent of processing type); the low separation demand condition was over all "easiest" and showed the highest level of accuracy as well as the fastest RTs, followed by the medium condition and lastly the high separation demand condition. The nature of these differences between conditions implies that the test material was successfully created to reflect the three different degrees of pattern separation demand. The high demand condition was indeed the toughest condition where participants' accuracy was the lowest and RTs the slowest, at the same time as the low separation demand condition proved to be the easiest. In sum, the three types of material fulfilled their roles as pattern separation demand test conditions.

Looking at the two factors' combined effects, how performance in the three conditions looked between blocks, only one condition displayed a difference in accuracy levels after local contra global processing – the medium separation demand condition. Performance in this condition was significantly better after local processing compared to global processing, suggesting that the NAVON blocks did carry over some sort of effect to the subsequent memory test – but at the same time, the other two conditions showed no sign of any such effects. While the nature of the high demand condition made it plausible that a local processing orientation would be beneficial to performance (at the same time as improved performance in the low demand condition following global processing would function as a proper reinforcement of the prediction), the results of the medium condition were a surprise since that condition was not paired with any specific prediction at all (not thought to be particularly benefitted or impaired by either type of processing). Perhaps the lack of effect of local processing in the high demand condition (and of global processing in the low demand condition) can be attributed to the precedence-less nature of the NAVON material used here. Perhaps it is the lack of a global precedence that made the global block not fully benefit the low demand condition, and the local block not really benefit the high demand condition. But why the material still managed to aid performance in the medium demand condition is hard to say.

One of the most interesting things that should be addressed in regards to the high and low demand conditions is the type of processing which they display their best mean performances in connection to. While both accuracy levels and RTs connected to the high demand condition were the best following local processing, responses to the items in the low demand condition were faster and more accurate following global processing.

Although these between-blocks differences were not statistically significant for either of the two conditions, it might still be valuable to note the way in which they both lean. The means display a shift in balance over blocks that, taken together with the effect of local processing on performance in the medium condition (suggesting some kind of power of the manipulation), might provide sufficient ground for the research question to still be interesting and relevant for future testing. With a set of NAVON material with characteristics closer to the original hierarchical letters, i.e. displaying a global precedence effect, it might not be too optimistic to hope for stronger effects of local processing on discrimination performance in the high demand condition.

Methodological alterations and improvements

Turning away from the discussion of how to best interpret the results, there are instead a few methodological choices to view in light of them. As mentioned above, one alteration to really consider if trying to test the question of this study further (local and global processing orientations' effects on recognition memory for material that differ in pattern separation demand), is the construction of the NAVON material. Wanting to present it within the square-system, and thus keeping the backdrop consistent over all items, the choice of coloring the letters differently was made here. This resulted in no real precedence effect (neither local nor global) and it is very possible that material more true to the original NAVON letters would bring other, stronger effects across tasks. The first, and one of the most central conclusions of this study is the possible necessity of global-precedence NAVON material in order for performance in the high demand condition to be improved by local processing.

In this experiment, the NAVON material was of linguistic nature and in the test phases all participants' used their right hand to signal their responses. Both these factors might carry importance to the result if viewed in light of the hemispheric lateralization hypothesis of how processing orientations operate – by priming activity in the hemisphere related to either coarse or fine-grained information (Borst & Kosslyn, 2010). Using only your right hand would prime activity in your left hemisphere (thus also priming for attention to local information), and processing linguistic information could potentially be priming your hemispheres in similar ways. Avoiding any kind of uneven, lateralized, activation being primed could be practically difficult. But perhaps switching NAVON letters to non-linguistic hierarchical shapes is one step, and controlling for handedness and the way participants register their answers is another if the aim is to avoid any risk of confounding results with imbalanced priming of hemispheric activity.

The way this experiment was designed, participants engaged in global or local processing both prior to encoding and retrieval. Results therefore tell us that a local focus, a detailed-oriented approach to the stimuli, is more beneficial to discrimination performance in the medium demand condition if used both while encoding and retrieving the information. A different design could aim at investigating either which encoding condition or which retrieval condition (global or local) would prove to be most beneficial for successful performance. If only using the manipulation task prior to either encoding or retrieval, one could compare a neutral phase and a manipulated one across blocks. By withholding the NAVON letters prior to encoding, only manipulating participants' focus at retrieval, results would tell us which type of primed processing would be best specifically in connection to retrieval. The practical issue then becomes the question of how long the NAVON effect stays in power, in an experiment such as this where phases and sequences followed on each other immediately, the local/global processing prior to one test-phase could easily have transferred to the study phase of the following sequence. Isolating the effect to either encoding or retrieval would probably mean creating a shorter experiment with longer intervals between sequences in order to avoid any NAVON effects carrying over between study phases and test phases.

The benefits of a long experiment is the opportunity it creates to collect a great amount of information from each participant. On the other hand, a long experiment can get exhausting and performance might be affected negatively. In this case the order of the two experimental blocks were balanced across participants so that any such negative effects would affect performances equally across both blocks. Nevertheless, one idea is to cut the experiment in half – instead of reusing the material over blocks, half the item-pool could have been used in one block and the other half in the other block. This would mean presenting two unique blocks of 36 items instead of two identical blocks of 72 items. Still reinstating the NAVON effect by presenting letters in-between study phases and test phases this would mean a shorter, more easy-going experiment for participants. This is not a suggestion based upon any signs of fatigue or negative effects on performance, which was in general very high – but it is suggested because of the similarities in performances between blocks. Maybe accuracy means would have differed more from each other across blocks if participants had been tested on block-specific items (presuming no items would display any outlier-characteristics, being either significantly easier or harder than the others). The downside of this shorter version of the experiment would be the smaller amount of data collected, something that might be compensated for by including more participants in the study. Following up on participants individual encoding strategies during testing could perhaps also provide interesting information about performance on an explicit memory task like this.

Future possibilities

Establishing a connection between pattern separation ability (performance in pattern separation-dependent tasks) and processing orientations/styles, would provide valuable behavioral information as to which psychological approaches and techniques could improve memory and learning. If a connection as the one hypothesized about in this experiment was observed in healthy adults through further trials (perhaps by adopting some of the methodological improvements and alterations suggested above) the research question could be highly relevant for studies with different age and patient groups. If the normal pattern separation ability can be strengthened or impaired by the choice of processing orientation, can performance be improved or impaired in older adults that already display weakened pattern separation abilities (Toner et al., 2009; Burke et al., 2010; Stark et al., 2010; Yassa et al., 2011)? Could the excessive generalization focus in anxiety patients, that is suggested to possibly be connected with weak pattern separation abilities (Sahay et al., 2011), be stabilized by techniques building on insights from studies like this?

We have seen that different factors have the power to positively affect neurogenesis and in turn spatial cognition and recognition performance in pattern separation-dependent tasks (Nilsson et al., 1999; Creer et al., 2010; Erickson et al., 2011), but is there also the possibility to see effects from the other direction; could psychological tactics improve pattern separation (even if only temporary), independent of being able to increase neurogenesis? Not only would it be interesting to investigate if various groups of people can be affected positively on pattern separation-dependent tasks, it would also be interesting to see if individuals probable to display good pattern separation performance are more likely to withstand negative effects. Would an older adult who exercises and solves cross-word puzzles be less negatively affected by global processing prior to testing compared to an individual without as good a foundation for neurogenesis stimulation? The possibilities for further experiments are many, and it all starts with establishing a basic connection between pattern separation performance and processing orientations.

Conclusion

Pattern separation is a process in which the detection of fine-scale differences in the patterns of neural activity caused by different input allows information to be separated into distinct representations in memory (Deng et al., 2010; Yassa & Stark, 2011). The process aids recognition by enabling the detection of new input based on very detailed information. Local processing prior to encoding and retrieval was predicted to match the local nature of highly separation-dependent test items and thereby be beneficial to discrimination performance in test situations high in pattern separation demand. This prediction draws from the results of several previous studies using local and global processing types to manipulate recognition performance, as well as the general principle of transfer appropriate processing. Although results did not support the specific prediction, local processing proved to be beneficial for performance in the medium separation demand condition, and means of both accuracy and response times revealed that performance at high separation demand was best following local processing, while performance at low separation demand was best following global processing. The results show enough promise to motivate further studies connected to the present research question, and the created material successfully reflected the three different levels of pattern separation demand, making it useful in further testing.

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