Internal Separating Overlapping Layers And Their Explanation

An alternative interpretation of the von Restorff effect

University of Linköping
Linköping
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Marcus Arenius
Charlotta Bengtsgård
Gita Berntsson,
Ludvig Granqvist
David Lagerlöf
Gesa Praetorius
Johan Tjernström

Background

Through the past 30 years it has become popular to use computational neuroscience to examine the brain and its functions. Neural networks are the main tool in this research. They are used to simulate brain activity in distinctive neural structures. Such networks help researchers to understand brain functions and mechanisms in greater detail. Different hypotheses can be tested by simply changing one of the many parameters and reasoning about the outcome. The research in this field of study is wide and there are shifting opinions about how biologically plausible such neural network simulations have to be to produce reasonable results.

In 1933 Hedwig von Restorff and Wolfgang Köhler published the article ”Über die Wirkung von Bereichsbildungen im Spurenfeld” (von Restorff 1933). The article discussed a memory phenomenon that has since been named the von Restorff or isolation effect. Via different memory experiments von Restorff and Köhler showed that some elements in a list are easier to remember than others; these elements were different from the rest of the list in some way. For instance a word coloured red, in a list that otherwise consisted of words coloured black, was easier to recall than the others. The differing word became known as an isolate.

Purpose

In this article the results of two different studies, a network simulation and an experiment, will be presented. The aim was to find out more about what causes the von Restorff effect. By modelling a neural network and further examining the von Restorff effect with an experiment and by integrating what researchers already have concluded, we hope to find some answers and perhaps an explanation for this phenomenon.

The von Restorff effect

Over the years the von Restorff effect has been found to be valid for list elements differing along the perceptual dimension like shape and colour, semantic categories or emotional biased elements (von Restorff and Köhler 1933; Hunt 1995; Fabiani and Donchin 1995).

Generally speaking, the effect has been attributed to attention; if an isolate is seen in a list, one focuses one's attention to the isolate and it is hence recalled better due to a higher level of encoding. If one has seen several common elements one might have established an expectation about what the common features are.

However, several researchers (e.g. Fabiani and Donchin 1995; Hunt 1995; Hunt & Lamb 2001; Sikström 2006) have pointed out that the effect cannot solely be a matter of attention. If an isolate is presented early in a list there has not been any time to build up an expectation of how the elements should look; leading to that there is nothing to draw attention.

The way the elements are encoded and subsequently recalled could solve this issue. If the elements were encoded into two separate categories depending on the elements' features, then it would be possible to classify which of the elements belongs to the isolate list and which belongs to the common one. The isolate can more easily be recalled since it is stored alone, whereas all the homogeneous elements are stored together leading to interference between them.

Different perspectives on the von Restorff paradigm

Hunt and Lamb (2001) chose a new perspective on the isolation paradigm. Instead of focusing on the isolate, the authors attributed the effect to the balance of similarity and difference among the elements in a list, hence creating an advantage for the isolated element.

According to Hunt and Lamb (2001) this is due to organizational and distinctive processing. Organizational processes result from encoding similarities among the different items in a list, while distinctive processes result from encoding similarities and differences among these elements.

A similar model of the von Restorff paradigm, as proposed by Donchin and Fabiani (1995), is based on three different phases of memory organisation; the encoding, the rehearsal and the retrieval phase. They further claim that there are two different levels of the encoding phase. In the first one, there is a parallel analysis of elementary stimulus features. In the second one, there is a more elaborate process of the stimulus features. The stimuli representation is compared to an ongoing memory representation which is most likely a higher level of cognitive processing.

Another interesting finding was that, if an isolated element was recalled by a participant, the total amount of words recalled was higher compared to a participant recalling no isolates. The conclusion drawn from the observations was that the total amount of words recalled increased proportionally to the number of isolates recalled, a so called set size effect (Fabiani and Donchin 1995).

Simulation

The approach taken in this simulation was to leave out short-term memory properties, since the original von Restorff study was on long term memory. This simulation mainly referred to the previously mentioned theories of Hunt (2001) and Fabiani and Donchin (1995). The simulation was conducted using leabra++, a network based on a combination of model learning using conditional principal component analysis and error-driven contrastive Hebbian learning. This combination of learning algorithms approximates learning in the human brain (O'Reilly 1998).

The aim was to design a network with no involvement of attention that can incorporate Hunt's theory of distinctiveness/similarity as well as the levels of processing suggested by Fabiani and Donchin (1995).

Two networks were developed that exhibited a von Restorff effect, the dual processing network and the semi-separating network. The dual processing network had two main layers, the Overlapping and the Separating. These two worked in conjunction to create unique and common features for each element. Both were needed to produce a von Restorff effect. The semi-separating network had one layer that maintained the two functions of the layers of the first network.

The two networks were tested via processes in leabra++ and the data they yielded were summarized and compared.

The results from the dual processing network and the semi-separating network both showed a clear von Restorff effect. This is because of the interference that occurs in the representation of the homogenous elements. Furthermore, the common elements were represented by similar weight configurations, thus getting a lower activation value than a unit (the isolated item) that is represented by a unique weight configuration. Neither network had any induced amnesia on the common element after the isolate. This is not very surprising since the effect is commonly attributed to attention which neither of the networks include.

By systematic testing of the dual processing network it was clear that the Separating layer was necessary to boost the isolation effect of the net. This affirms Hunt's theory of the importance of distinctiveness and similarity as the Separating layer is functionally responsible for distinctiveness.

When it came to set size, it was noted that the dual processing network did show a tendency towards this phenomenon.

Furthermore, both networks showed some interesting results as a side effect of the set size simulation. The dual processing network revealed that the elements within the part of the list containing the isolates were on average better recalled than the members of the list containing the common elements. This showed that the isolates were less affected by interference from each other when they were encoded than the common elements. The isolates were represented as one group in the Overlapping layer and the common were represented as another group. Interference in a group increased the larger that group was, so a group containing few elements had better recall than a group containing many elements.

Experiment

In addition to the network simulation an experiment was conducted to further investigate how the set size effect functions. The experiment had between one to six isolates in a list of twelve elements. By comparing the different lists, a set size factor was searched for.

The experiment had a clear isolation effect and showed a tendency towards a set size effect. Tendencies of induced amnesia were observed during the experiment.

General Discussion

As mentioned earlier one of the main purposes of this study was to show that the von Restorff effect cannot be accounted for completely as a result of attention. Even if attention might have had influence on the outcome of the experiments, it was possible to recreate the von Restorff effect in a neural network completely without any attention mechanism.

Set Size

The results of the experiment show a slight set size effect in the case of one isolate in an homogenous list. It indicated that the average number of recalled items was higher than in the recall of the control list. Unfortunately the results did not reflect a higher degree of set size effect although this was expected. This might have been caused by the way in which the different lists were organized. The isolated elements were not isolated from each other, they shared the same distinct feature, in this case colour. As a consequence the isolates might have been organized as just another homogeneous list instead for being processed as isolates.

During the simulation the dual processing network indicated the same tendencies regarding set size as the experiment. The more isolates that were remembered the more elements were recalled in total.

Induced amnesia

Another relevant fact for the simulation was a tendency of induced amnesia indicated in the results obtained in the experiment. One of the lists, the one with the isolates, was preceded by a control list thus providing a context. As the isolate was presented later on, it attracted attention as it was differing from the established context. This was initially not intended but proved valuable as only the result of this list configuration showed a significant induced amnesia effect, which is commonly attributed to attention (Tulving, 1969). The other lists, that were not preceded by a control list, did not show this significant induced amnesia effect and it is thus reasonable to conclude that the simulation should not either, which it did not.

Fabiani and Donchin (1995) stated that the isolation effect occurred because of the isolate and the homogenous elements were stored in different lists. Therefore interference arises between the homogenous elements as they share the same storage space; the isolate on the other hand is stored separately. This hypothesis was affirmed by the conducted simulation as the analysis of the representation of the different elements in the Semi-separating layer showed that the isolate did not share any weights with the other elements.

Reed Hunt refined Fabiani's and Donchin's model (1995) further. He pointed out that the reason why the isolate is stored separately from the homogenous items was its advantage in terms of balanced similarity and difference processing. Hunt (1995) also stressed that this phenomenon was not solely due to attention. This is why the balanced processing can explain the isolation effect even if the isolated element is presented on a position where the lack of context would prevent it from being recognized as an isolate.

The previously mentioned psychological concepts were guidelines for the design of the simulation. In the dual processing network, the layer processing differences and the layer processing similarity cooperated in order to successfully produce a von Restorff effect. In the semi-separating network the same effect was evoked; the processing of differences and similarities was present.

The net's construction is also grounded in biological findings. As Nyberg (2005) suggested in his studies the hippocampal neurons in connection with areas in the medial temporal lobe are essential for the von Restorff effect. Lesion studies with patients with damage in the hippocampal area indicated, that they were not able to show an isolation effect in recall situations.

Research conducted in the field of computational neuroscience indicated further that the Dentate Gyrus area in the hippocampal memory system fills a memory-relevant function through extreme separation of the incoming stimuli (O'Reilly 1998). This strongly resembles our Separating layer in the dual processing network simulation, thus this layer is supported by psychological (coding differences) and neurological frameworks. However, as Nyström (2005) argued, other systems also tend to be involved. This is why the Overlapping layer was introduced, the functional equivalent to the process of coding similarities.

The semi-separating network combines the different areas associated with memory into one integrated system while preserving their distinct functionality. It is still unclear if this is a standard procedure but the obtained data from the two simulations strongly suggest that they, at least in terms of performance, are nearly identical.

Fabiani and Donchin (1995) essentially divided the von Restorff effect into 3 different phases, the encoding, rehearsal and retrieval phase. The neural networks presented in this report focuses on the first of these three phases, the encoding phase. Fabiani and Donchin (1995) divided this phase further into two levels based on PET-scanning studies.

The first level in this model is functionally responsible for parallel processing of simple features, where the isolate is deviant in some dimension. The second level is more elaborative which leads to the fact that the stimulus presentation is compared to an ongoing memory representation that is tied to higher cognitive processing.

The simulation presented in this report can be said to be located in the first of the two levels of processing. It analyses the input features, with one input, the isolate, being deviant in a significant way.

The processing taking place in the net leads to a separate storage of the memory representations. The isolate is placed in one location and the homogenous elements in another. This could be seen in the cluster plot analysis in the result section of the simulation. This is consistent with Fabiani and Donchin's notion (1995) of the isolate being recalled better because it alone is placed in a separate category while the homogenous elements share the same one; therefore suffering from interference. The simulation does not incorporate the second level of encoding which could be regarded to be responsible for semantic or emotional isolation effects.

In this case the higher cognitive processing is responsible for the isolation effect and not the features of the presented data per se. For example, if participants are presented with a red word after a ten black, then the isolating feature is intrinsic for the word and an isolation effect will probably occur later on at recall.

However, if the word is deviant in its semantic category, nothing in the word's perceptual features implies that it should be processed differently. For example, the word "water" in a list consisting only of words concerning furniture does not contain significantly different perceptual features compared to the other elements in the list. Still, it leads to an isolation effect at recall. This can be attributed to higher cognitive processing, which is equivalent to the second level of encoding. To be able to create such an isolation effect depending on semantic deviance in a network simulation, a context layer would be needed in which semantic knowledge and emotional biases would be represented, that could modify the incoming input.

If a semantic deviant element is processed by this context layer, its output would be in the same shape as the input in this simulation. Thus, it could be argued that it could fill a double purpose. On the one hand, the simulation is able to produce the von Restorff effect from perceptually deviant elements. On the other hand, it could in cooperation with a context layer also account for semantic and emotional isolation effects. Implementing this kind of higher cognitive processing is an issue for further research.

Conclusion

This study attempted to interdisciplinary argue for a new interpretation of the von Restorff effect, excluding attention as imperative cause.

Several different fields of study were integrated into the simulation, ranging from psychological research over neurological findings to the most recent advances in computational neuroscience regarding biological plausibility. In addition to that, behavioural data was derived from an conducted experiment and integrated into the study.

By explaining behavioural phenomena in terms of biological processes, hopefully this paper contributes to the timeless task of bridging the gap between brain functions and behaviour.

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