A Global Memory Model Perspective on the Revelation Effect

Thesis in partial fulfilment of the requirements for the degree of Bachelor of Science (B.Sc.) in Psychology

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ABSTRACT

In recognition tasks, participants tend to show a positive response bias when a revelation task precedes the recognition item (Watkins & Peynircioglu, 1990). This bias is called the *revelation effect*. Although the revelation effect has been investigated a lot over the past two decades, the underlying processes still remain obscure. According to the Global Memory Model MINERVA II, the effect is caused by context loss after the revelation task. Item frequency influences the magnitude of the effect (Zaiser, 2015). Recently, a negative revelation effect occurred in an experiment by Aßfalg and Bernstein (2012). The present study replicates the findings of these authors with different stimulus material. Additionally, it shows that item frequency has a significant influence on the magnitude of the effect.

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1 Theoretical Background

Our memory plays an important role in shaping our personality. When we observe patients who lost their memory, it becomes obvious how crucial memory is for our identity. Dissociative disorders such as the *dissociative fugue* demonstrate that people might lose all connection to their personality and former life while suffering from amnesia (Davison, Neale & Hautzinger, 2007). Not only with a pathologic disorder, but also in our normal everyday life, memory is not perfect. Mostly we do not notice that the underlying processes are highly vulnerable to distortions and biases that induce false memories. To give an example, we estimate an event to be more predictable after its occurrence than before its occurrence. This bias is called *hindsight bias* (Fischhoff, 1975). The present work is about another bias, the so-called *revelation effect* (Watkins & Peynircioglu, 1990). Being a quite counterintuitive as well as a very robust effect, the investigation of it might foster conclusions about the underlying processes of memory. Although the size of the revelation effect is rather small, it has been shown that its impact may be fairly great – for example, when it comes to advertising (see Kronlund & Bernstein, 2006). In this paper, I will present a selection of research on the revelation effect and theoretical approaches that try to explain its many facets. Then, I will focus on Global Memory Approaches, more precisely on the model MINERVA II (Hintzman, 1984). Finally, the predictions of the model will be tested in an experiment on the revelation effect.

1.1 The Revelation Effect – Previous Research

The revelation effect refers to a phenomenon that appears in recognition testing. In the typical procedure, participants first learn a list of items, for example words. In the second step, they complete a recognition test. In the test, they have to decide whether the probe item has been on the study list (*"old"* item) or not (*"new"* item). Prior to half of the probe items, the participants solve a revelation task. For example, they unscramble the anagram *YVIANDER* before deciding whether the word *VINEYARD* has been on the study list. It has been shown that test participants are more likely to label a recognition item "old" when it appears in a disguised way and has to be revealed. The revelation task is typically an anagram task (Watkins & Peynircioglu, 1990; Westerman & Greene, 1996) or a task to guess the complete word when it is presented only partially and revealed letter by letter (e.g., Watkins & Peynircioglu, 1990; Luo, 1993). However, the effect generalizes largely. Thus, the it also occurs when the recognition item is disguised through rotation (Watkins & Peynircioglu, 1990) or through reversed order of letters (Luo, 1993). The effect was found for numerical item material (Watkins and Peynircioglu, 1990) and for arithmetic problems (Niewiadomski & Hockley, 2001, but see also Westerman & Greene, 1998). Moreover, Westerman and Greene (1998) proved that it also occurs when participants solve anagrams of non-words or engage in a memory span task prior to the recognition test. Typically, the revelation task influences both targets and lures. But the effect is greater on lures than on targets (for a meta-analysis see Hicks & Marsh, 1998).

Only a few limitations have been reported for the revelation effect. For example, the effect only occurs for memory tests that are connected to episodic memory. For instance, Watkins and Peynircioglu (1990) failed to observe it in a test for word category decisions, lexical decisions and in a test for frequency judgements of words in everyday life. Besides, the revelation effect does not appear for very rare words or non-words when they have been presented and tested in a mixed list with common words (Hockley & Niewiadomski, 2001). I will emphasise this point later in this work.

1.1.1 Early Approaches

Several attempts have been made to explain the revelation effect. In the following section, I will outline the major theories of the past three decades. The first, intuitively plausible explanations for the revelation effect were ruled out quite soon. Peynircioglu and Tekcan (1993) hypothesized that the revelation effect occurred due to extra effort or extra time spent on the revelation item. In their model, this increases the familiarity of the critical items and leads to a higher magnitude of the effect. However, in their first three experiments, the authors could not observe a correlation between the amount of time spent and the proportion of “old” answers. The hypothesis was again rejected by Westerman and Greene (1998), when they substituted the revelation task with a delay of ten seconds. In this experiment, no revelation effect occurred.

Furthermore, Peynircioglu and Tekcan (1993) tested another, quite intuitive theory. What if the revelation item reminds participants of other words in the study list by perceptual or conceptual fluency (see also Luo, 1993)? Then they might misattribute the increased familiarity to the revelation item and give more “old”-answers. However, Peynircioglu and Tekcan (1993) refuted this idea in three experiments. Additionally, Westerman and Greene (1996) provided evidence against it as they detected a revelation effect, even though the revelation item did not match the following recognition item (see also Bornstein & Neely, 2001, Experiment 2). For example, if the revelation task consisted of the anagram *YVIANDER* [*VINEYARD*], participants had to decide whether the subsequent probe *RAINDROP* had been in the study list or not. This finding was a mile stone for research on the revelation effect, prefiguring that explanations would not be as simple as supposed before.

1.1.2 Criterion Shift

The so called *signal-detection theory* is a framework to describe decisions of participants under uncertainty (Baddeley, Eysenck & Anderson, 2015). Thus, also the decision of a participant whether to respond “old” or “new” in a recognition test can be investigated with the methods of the signal-detection theory: familiarity strength of targets and lures is depicted as normal distributions that might overlap to a greater or lower extend (Baddeley et al., 2015). According to the theory, the answer of participants depends on the distance *d’* between the peaks of the two strength distributions of old items and new items (Baddeley et al., 2015). The distance *d’* can be seen as a sensitivity measure: the greater the distance between the peaks of the distributions, the more certain participants will be about their answer (see Figure 1). However, the decision of participants to call an item “old” or “new” also depends on their individual decision criterion (Baddeley et al., 2015). Above the criterion, participants label an item “old”; respectively, if they perceive familiarity of an item as lower, they label it “new” (see Figure 1).

Based on the signal detection theory, several authors make the assumption that the revelation effect is due to a shift of the answer criterion (Hicks & Marsh, 1998; Niewiadomski & Hockley, 2001; Hockley & Niewiadomski, 2001). Hicks and Marsh (1998) suggest that the revelation task activates several competing memories. The competing memories interfere with the memory of an item being on the study list. This leads to a decrease of the signal-to-noise ratio and consequently to a more liberal criterion for the recognition answer. That is, the revelation task reduces familiarity and increases test difficulty, resulting in a criterion shift to the left and more “old”-answers (see Figure 1). Yet the work of Niewiadomski and Hockley (2001) takes issue on this theory: the authors found that arithmetic tasks produce a revelation effect on study words as well as common verbal problem tasks (but see Westerman & Greene, 1998). How can competing memories, activated by an addition task, interfere as much as competing memories of a verbal task? Therefore Niewiadomski and Hockley (2001) modify the approach: the revelation task might rather interrupt participants during the recognition test. Thus, they lose a part of context information which they would need to set the criterion appropriately. For the first probe after the revelation task, they fail to completely reinstate the context. Consequently, they face a decision of uncertain difficulty. The uncertainty leads to a more liberal criterion for the first item after the revelation task. From the second probe after the task, participants are able to fully re-establish the criterion and the positive decision bias disappears. Being quite undifferentiated, the model of Niewiadomski and Hockley gains support from various studies that show the generality of the effect. Additionally, the authors showed that the magnitude of the effect stays the same with two interposed revelation tasks, compared to only one (Niewiadomski & Hockley, 2001). This represents one of the predictions of the model because one problem task should be enough to displace context information. Although being rather unassertive about concrete processes and predictions, Niewiadomski and Hockley's idea of context loss during the revelation task is to be considered further. I will return to this point later in this work.

Nevertheless further research has shown some inconsistencies with the criterion shift approach. Firstly, when participants were told to respond "yes" to items they had *not* seen in the study list, they still labelled revealed items more often as having been part of the study list than unrevealed items (Westerman & Greene, 1996). Thus, the criterion shift does not always tend towards a more positive direction. The problem is that it is not clear which factors influence the direction of the criterion change. Moreover, it might be worth taking notice of the limitations of the signal detection theory in context of recognition answers. Firstly, an important assumption of the model is that the variances of the two distributions are equal (Verde & Rotello, 2003). However, this is not always the case for recognition tasks. Typically, the distribution of old items has a greater variance than the distribution of new items (Verde & Rotello, 2003). Secondly, in literature, *d'* and the response criterion are calculated separately for the intact and the revelation condition (e.g., Niewiadomski & Hockley, 2001). In any case, the mean of the distribution for lures is normalised to zero (Wickens, 2002). Hence, the possibility of an equal change of both distributions in the same direction is not included in the model. Therefore, if it is the case that both distributions shift to either side with the same extend, calculations will attribute the change to a criterion shift and not to a shift of the distributions (see Figure 2).

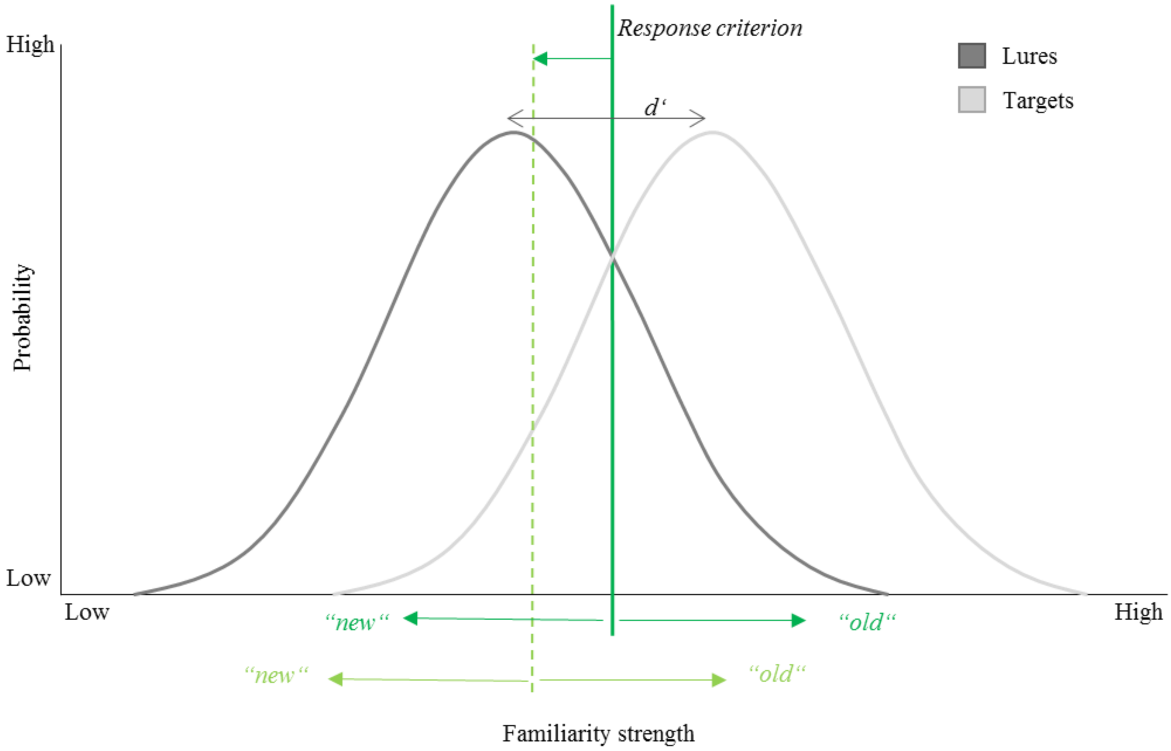

Figure 1. Criterion shift approach: After the revelation task, the response criterion moves to the left, resulting in a higher proportion of "old"-answers. Depicted are the distributions of familiarity strength for lures and targets, the sensitivity measure *d'* and the response criterion. Adapted from *Memory*, by A. D. Baddeley, M. W. Eysenck and M. C. Anderson, 2015, London: Psychology Press.

1.1.3 Familiarity Change

Some researchers consider recognition as a dual process (e.g., LeCompte, 1995; Westerman, 2000; Landau, 2001). According to the *dual process theory*, the recognition process consists of *recollection* on the one hand. This describes the conscious remembrance of items in the learning situation. But, sometimes participants might not remember the situation consciously although they have a feeling of knowing the item. This *familiarity* is the second component of the dual-process model.

There has been some support for this hypothesis: LeCompte (1995) measured the influence of recollection and familiarity on the revelation effect with two different procedures, namely the *process-dissociation procedure* (Jacoby, 1991) and the *remember-know procedure*

(Tulving, 1985). Both of LeCompte's experiments suggest that the revelation task influences only the familiarity component. However, recollection might play a secondary role by decreasing the influence of familiarity. Another argument in favour of this is that the revelation task has a higher impact on lures than on targets. Suggesting that a change of familiarity is the source of the revelation effect, this might be because recognition of targets depends on both familiarity and recollection (LeCompte, 1995). The familiarity approach gains further evidence from a study of Westerman (2000): in her second experiment, participants studied a list with singular and plural forms of words and were tested on them later. In this case, participants could not rely on familiarity, because this would not have been sufficient to distinguish between the singular and the plural form of the word. Westerman suggests that the participants have to use recollection in this case and thus the revelation effect should disappear. These predictions were reflected by the data. Besides, Cameron and Hockley (2000) found that the revelation effect disappears in an associative recognition procedure: when the participants learned pairs of words and were tested afterwards with an item recognition test versus an associative recognition test, the effect disappeared in the latter. According to the authors, participants might not be able to decide whether two items have been presented together by using only familiarity. Thus, they use the recollection strategy – which eliminates the effect. In the same paper, Cameron and Hockley report that the revelation effect reappears for very short study time. In the author's opinion, participants do not have sufficient time to build associations between the words in this case and consequently rely on familiarity again.

But why and how does familiarity change after a revelation task? Westerman and Greene (1998) offer a *Global Memory* approach: By solving the revelation task, the revelation item, thus the item of the anagram solved prior to the recognition test, and similar words stored in memory might get more activated and the participants misattribute the resulting increased familiarity to the incidence of the word in the study list. Thus, speaking in terms of the signal detection theory, not the decision criterion shifts to a more liberal position, but the familiarity distributions move to the right, resulting in higher hit and false alarm rates (see Figure 2). The approach of Westerman and Greene (1998) has been rejected soon. Verde and Rotello (2003) showed that the size of the revelation effect does not depend on whether the revelation item is a previously studied or a new item. Furthermore, similarity between revelation item and recognition probe does not affect the magnitude of the revelation effect (Verde & Rotello, 2004, but see Bornstein, Robicheaux & Elliott, 2015). This poses a huge problem for Westerman and Greene's approach, over all when revelation item and probe are very similar.

Familiarity certainly plays a role in the occurrence of the revelation effect. But so far, research lacks of consistent models about the underlying processes. Later in this work, I will present a Global Memory Model which could fill this gap.

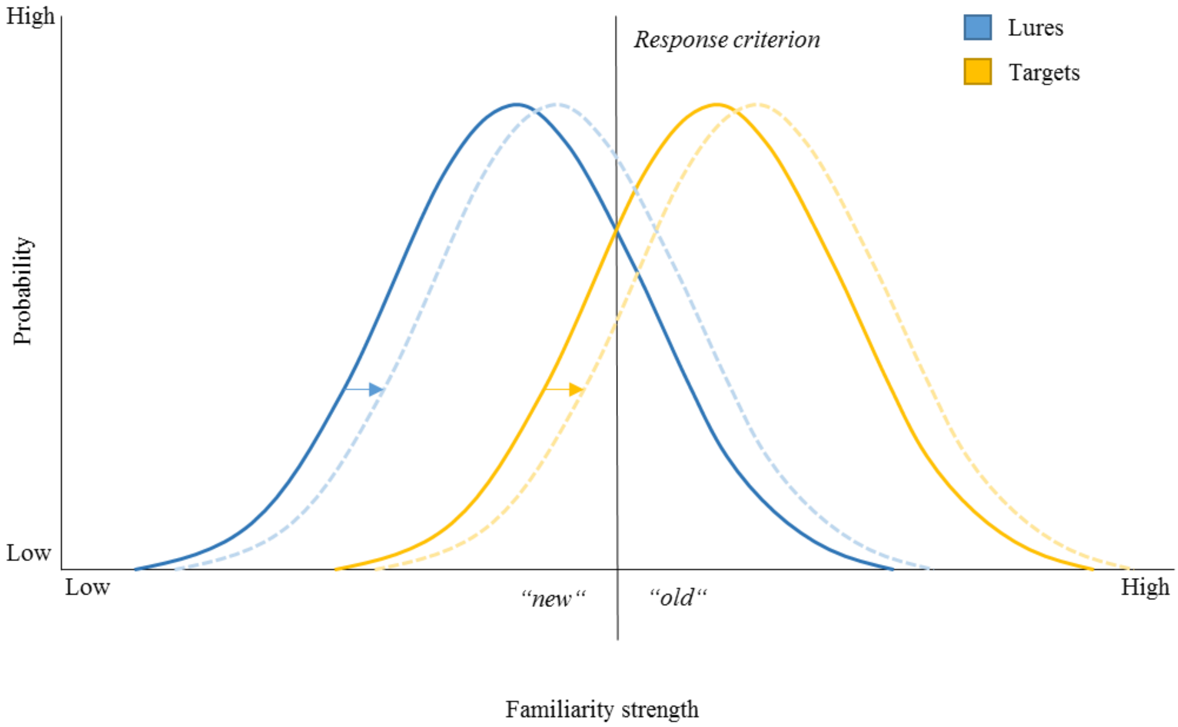

Figure 2. Familiarity shift: Through the increased activation of memory, familiarity distributions shift to the right. Depicted are the distributions of familiarity strength for lures and targets and the response criterion. Adapted from *Memory*, by A. D. Baddeley, M. W. Eysenck and M. C. Anderson, 2015, London: Psychology Press.

1.1.4 Fluency Misattribution

Whittlesea and Williams (2001) offer quite a different approach. They put the revelation effect in context of the *discrepancy-attribution hypothesis* (Whittlesea & Williams, 1998). According to the theory, people evaluate processing ease of preceding tasks and draw information about the expected ease for the next task. If the task difficulty does not match expectations, they misattribute the unexpected fluency to familiarity. Because the revelation task is more difficult than the following recognition task, participants experience the recognition task as fairly easy. Consequently, they misattribute the easiness of the task to a higher familiarity of the probe. This leads to a higher proportion of "old"-answers, that is, to the revelation effect. The theory explains satisfactorily, why it is negligible whether the revelation item and the probe are related or not (c.f. Westerman & Greene, 1996). Moreover, Frigo, Reas and LeCompte (1999) found a revelation effect when participants only thought that they had studied a list of items (but in fact did not). In another experiment with the same idea, the effect disappeared when participants were conscious about the fact that they had not studied a list before (Frigo, Reas & LeCompte, 1999). According to discrepancy-attribution, participants have the possibility to misattribute the unexpected fluency to a study list in the first case. Conversely, in the second case they know that they cannot attribute fluency to familiarity because they have not studied any item before. Thus, the familiarity remains constant and the revelation effect disappears (Aßfalg & Nadav-eric, 2015).

1.1.5 The Negative Revelation Effect

A major problem for the discrepancy-attribution hypothesis is the occurrence of a *negative* revelation effect. In the concerning experiment, participants studied a list of faces and had to recognize them later. A revelation task, namely a puzzle task of the faces, preceded half of the recognition items. Very surprisingly, the revealed face items were more likely to be labelled *"new"* than the other items (Aßfalg & Bernstein, 2012). This negative revelation effect was neither expected by the authors nor by any theory discussed so far. In fact, Bornstein and Wilson (2004) already experimented with faces as stimulus material. Yet, they asked the participants to rate faces for attractiveness when being presented upside down as revelation task. With this design, the common positive revelation effect occured (see also Aßfalg & Bernstein, 2012, Experiment 1). With this background, Aßfalg and Bernstein (2012) try to explain the appearance of the negative effect with an over-discounting hypothesis (c.f. Oppenheimer, 2004; Wegener, Petty & Dunn, 1998): due to the very salient puzzle task, participants might become aware of the different difficulties of the tasks and counteract in terms of avoiding the risk of a too high estimation of familiarity. Thus, they over-compensate and show a bias in the opposite direction. However, contrary to the predictions of the over-discounting hypothesis, participants do not over-discount when they previously have been enlightened about the effect (Aßfalg & Nadav-eric, 2015). Although the authors warned their participants about the influences of the revelation task and ensured that they noticed and understood the instructions, the typical positive revelation effect appeared. Hence, the over-discounting hypothesis fails to explain the answering behaviour of the participants in Aßfalg and Bernstein's experiments.

The negative revelation effect questions all theories discussed so far. However, in the following sections, I will present a *Global Memory Model*, *MINERVA II* (Hintzman, 1984), which is not only capable to explain the patterns of occurrence of the positive revelation effect so far, but also the negative revelation effect. In retrospect, it is striking that literature on the revelation effect lacks of theories which make clear predictions about when and to what extend the effect occurs and when it stays absent. A surprisingly big part of the research about it consists of post-hoc explanations instead of guiding theories. Concrete factors, which might influence the effect, have been elusive. In this work, I will present determinants that have an impact on the revelation effect, according to MINERVA II. Based on the theory, I will describe an experiment which demonstrates the predictions of the model.

1.2 Global Memory Models

In literature, many attempts to structure the memory process can be found. For example, in a work edited by Norman (1971), more than 15 memory categories in 13 essays have been described. In today's literature, memory processes are mainly divided into *encoding, storage* and *retrieval* (Baddeley et al., 2015). Within storage, one can differentiate between *episodic* and *semantic* memory (Tulving, 1972): temporally dated events are stored in episodic memory, such as *'I remember that I travelled to Paris last summer.'* Semantic memory refers to knowledge about the world we have (Tulving, 1972). For example: *'I know that Paris is the capital of France. But I don't know when I learned this.'* Moreover, some researchers subdivide retrieval into a dual process (Yonelinas, 2002). I already discussed an example of a dual-process model in this work: the distinction between recollection and familiarity (Whittlesea & Williams, 2001). All these differentiations arise from the attempt to explain why memory behaviour differs in various situations. For example, one might ask why one does not remember the time of learning that Paris is the capital of France. In contrary, they know exactly when they have been to Paris for the first time. Although the two questions are highly related to each other, memory presents itself quite differently. A fairly easy solution for the problem is, to categorise memory into different parts – in this case semantic and episodic memory – each with different processes and implications. However, Global Memory Models are unidimensional. That is, the models aim to include episodic and semantic storing or recollection and familiarity retrieval all in one model. And although the basic idea is fairly simple, many subdivisions get redundant, being included in the implications of a global activation memory process.

But what aspect in these models makes them *global*? In competing theories, the *local* approaches, retrieval is assumed to work sequentially (e.g., Tulving, 1976; see Clark & Gronlund, 1996, for an overview). Thus, in a recognition test, memory is searched for a representation similar to the probe. As soon as the correct representation is found, the search process stops and participants answer “old”. If no memory representation matches the probe, the answer is “new”. In contrast, in Global Memory Models, the probe activates *all* traces in memory. Thus, every trace that was stored influences the answer of the participant. This approach gains evidence from research on recognition tests. For example, the participants’ answering accuracy depends on the length of the list they have studied (*list-length effect;* e.g., Strong, 1912) and on the strength of the words they learned (*list-strength effect;* Clark & Gronlund, 1996).

1.2.1 MINERVA II

MINERVA II of Hintzman (1984) is not only a Global Memory Model, but also a *formal* model. That is, it consists of clearly defined variables, which can be included in computer simulations, resulting in quantifiable and verifiable predictions (Clark & Gronlund, 1996; Brandt, 2007). The model bases on the idea that every event or item in human memory is stored individually as a vector of numbers (Hintzman, 1988). The vector includes information about various features of the item. One element in the vector corresponds to a feature of the stored item. Elements in the vector can take the values 1, -1 and 0. If one feature is defined and true for a specific item, the corresponding element of the vector takes the value 1. If the feature is defined for this item but evaluates to false, the element for this feature takes -1. If a feature is not defined or if there is no information available about this feature for this specific item, the corresponding element is set to 0 (Hintzman, 1988). For example, for the item *table*, a feature *‘has four legs’* would take the value 1 – thus true. However, the feature *‘is a fish’* would be coded with -1 – thus false. *‘Likes chocolate’* is not defined for the item *table*, therefore the corresponding component of the vector would be set to 0. To store an item, the encoded features of the item form an item vector (Hintzman, 1988). However, the process does not work perfectly. It may happen that memory misses some of the features unintentionally. In this case the feature takes the value 0 instead of 1 or -1. The probability of coding a feature correctly is called *learning rate*. It takes values in the range $0 \leq x \leq 1$. The learning rate is independent for every feature-item combination (Hintzman, 1988). If participants learn an item repeatedly, they will store it separately every time. Thus, it is likely that the vectors for a repeatedly learned item may vary slightly. They may also differ from the original item in different ways (Hintzman, 1988).

According to MINERVA II, retrieval never happens spontaneously. In every case, a cue item is necessary as a trigger (Hintzman, 1988). Like the stored items, the cue item is defined as a vector. It activates all content in memory – meaning all stored vectors – in parallel (see Figure 3). The result of the activation is called *echo*. All stored items in memory influence the echo, while vectors with the greatest similarity dominate. However, it varies for different cue items, depending on the similarity to every stored vector. Each comparison between probe vector and stored vector produces an echo component. The greater the similarity between cue vector and stored vector, the higher the intensity of the echo component of this particular stored vector. The sum of the intensities of the echo components is the intensity of the total echo. Thus, the more stored vectors match the cue item and the better they match, the higher the intensity of the total echo. Random similarities of irrelevant vectors even out to 0 (Hintzman, 1988).

The probability that participants classify an item as “old” in recognition tests depends on the total echo that it evokes. But how do participants know whether the item has been on the list or has just appeared in some other situation in the past? So far, the model only included the items of a specific study list. However, memory of participants does not barely consist of the studied items but of millions of items they have learned before. These *extra-list items* also have an impact on the total echo in a recognition test (Zaiser, 2015; see Figure 3). In fact, they distort the accuracy of the answering behaviour by adding echo intensity to the output. The magnitude of the added intensity depends on the similarity of the extra-list items to the probe. Thus, if the probe is a very well-known word, that is, a *high-frequency* word, extra noise coming from the extra-list items is quite strong. In contrast, if a probe word is rather uncommon, there are not many extra-list items in memory that match the probe. Then the noise approaches zero and the answer turns out fairly accurate. Unfortunately, there are hardly any words that do not match with any of our extra-list items. However, list homogeneity is a factor which is able to protect retrieval from the disturbing influence of extra-list items (Schnürch, 2014; Zaiser, 2015). The assumption that stimulus material – or more precisely: intra-stimulus similarity – influences recognition performance has been shown in various studies (e.g. Kinnell & Dennis, 2012). Thus, if the items of the list are sufficiently alike, and if targets and lures have approximately the same number of matching extra-list items, there is a much higher intensity for targets than for lures. This is because the vector of a target matches the vectors of the list items much better than the vector of a lure.

The key why this mechanism also works for lists that are not manipulated for homogeneity are so called *context features* (Zaiser, 2015; see Figure 3). These features contain information about the time and the learning environment of the study list items and the associations participants had. For example, if participants learn the item *table,* they will also encode temperature and light of the study room, and additionally think of which items they have learned just before or the association that their grandfather once made a table on his own. All these features get stored in memory by learning the item. Hence, the study list is highly homogeneous, because all items share approximately the same context information. That is, a high proportion of the features are the same for all of the items of the study list (see Figure 3). If a probe item is old, then both the item features and the context features are the same like one of the item vectors of the study list. Additionally, the context features of all studied items match the probe. Consequently, it evokes a higher echo than new items do.

In summary, three factors have an impact on the retrieval process:

1. *Frequency*, that is, the number of extra-list items of the probe item.

2. *Homogeneity* of the study list.

3. The *context* of the learning situation.

How these factors act in context of the revelation effect is the subject of the next section.

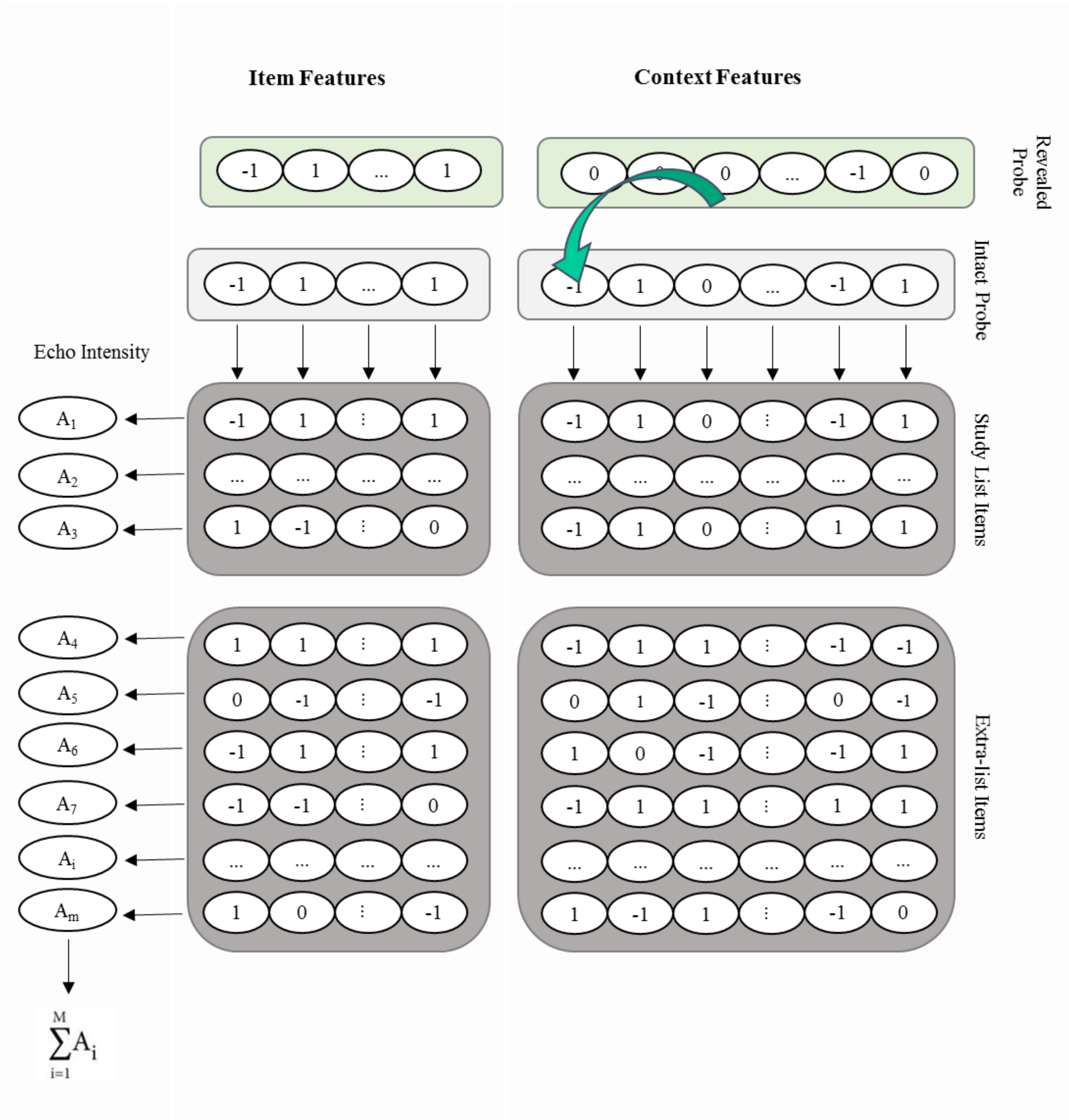

Figure 3. Context loss: after the revelation task, encoding the context of the recognition probe item is impaired. Depicted are item features and context features for study list items, extra-list items and the probe (old; intact vs. revealed case). By comparing the probe vector with item vectors in memory, every single item produces an echo activation A_i. The resultant total echo is the sum of all single echo activations. Own representation, partially adapted from “Judgments of Frequency and Recognition Memory in a Multiple-Trace Memory Model.” by D. L. Hintzman, 1998, *Psychological Review, 9,* p. 529.

1.2.2 MINERVA II as an Explanation for the Revelation Effect

In the standard procedures of the revelation effect, a revelation task interrupts the recognition test. To solve this task, participants do not need context information, as the task does not require to know in which context the item occurred (Zaiser, 2015). Thus, participants neglect the context features of the revelation item to be able to focus on the revelation task itself. For the following recognition item, the switch to a recognition task again – and thus refocusing on the context features – does not work properly. In this case, the context is only partially encoded. In Figure 3, an intact probe – thus, an item without a preceding revelation task – is depicted. The context of the intact item is correctly encoded. Thus, the vector of the context features of the intact probe consist mostly of the elements 1 or -1. In contrast, if the item has to be revealed prior to the recognition test – thus, is a revealed probe – the information about the context gets lost and elements of the context features are mostly set to 0. The homogenising effect of the context features decreases and extra-list items have a greater influence again (Zaiser, 2015). If the probe word is a high frequency word, many of the extra-list items match the probe word. Thus, the echo intensity increases with the revelation task. Indeed, as mentioned earlier, Cameron and Hockley (2000) tested the revelation effect in the associative recognition procedure: Participants studied pairs of words and later had to recognise either single items or word pairs. In some of the cases, an anagram task was posed prior to the recognition test. The revelation effect only emerged in the single item recognition test, not when the word pairs were to be recognised. According to MINERVA II, this is plausible, because in the latter case, context loss after the revelation task was compensated by presenting the paired word, thus an important part of the context of the learning situation.

Importantly, if the probe word after the revelation task is of low frequency, little extra-list items match and exert influence on the total echo. In this case, the intensity can be even lower than the “normal” activation, which emerges when the context is encoded accurately. Thus, a negative revelation effect occurs. Experiments about the revelation effect have mostly used words as item material. Since we read words quite often in our life, most words have many matching extra-list items. In contrary, faces are assumed to be low frequency material since the participants have never seen these specific faces before. There is some further evidence that item frequency might have an impact on the occurrence of the effect. Peynircioglu and Tekcan (1993) found a greater false alarm rate for high frequency words than for low frequency words. Furthermore, no effect was found for very rare words when they had been studied in a mixed list with common words (Hockley & Niewiadomski, 2001, Experiment 3). And a negative revelation effect occurred for non-words, having been presented in the same list with common words (Hockley & Niewiadomski, 2001, Experiment 4). More recently, Zaiser (2015) analysed her results in a post-hoc analysis with regard to item frequency and found a negative revelation effect for low frequency words.

In the following experiment, I manipulate all three crucial factors discussed in this section. Homogeneity was manipulated by using only pictures of houses as stimulus material. Context loss was manipulated through a revelation task and frequency in the form of choosing low frequency material on the one hand and presenting the items frequently on the other hand.

2 Experiment

The negative revelation effect is a response bias for participants to label the item after a revelation task “new”. According to MINERVA II, it appears when item material of the recognition test is of low frequency. Then, only few extra-list items match. Due to the preceding revelation task, participants fail to encode the context of the probe item completely. Consequently, the study list’s influence on the familiarity echo decreases and extra-list items gain greater impact. Due to the low echo coming from the study list items and the low echo from the extra-list items, the familiarity for revealed items is lower than the familiarity of intact items, thus probes that were not disguised before. Hence, a negative revelation effect appears. By increasing the number of extra-list items, the magnitude of the negative revelation effect should decrease. Or, in an extreme case, it should reverse to a positive revelation effect.

2.1 Hypotheses

The purpose of the present study was to replicate the negative revelation effect with different item material. Aßfalg and Bernstein (2012) claim that the negative effect occurs because the puzzle task disrupts the holistic processing of faces by taking them apart (see also Yin, 1969; Tanaka & Farah, 1993). For the present experiment I used pictures of houses which are not processed in a holistic way when presented intact (Gazzaniga, Ivry & Mangun, 2002). Nevertheless, I expected to find a negative revelation effect. This would rule out the holistic-processing explanation. Moreover, I aimed to prove the influence of an increasing number of extra-list items. To do this, participants ran through three blocks. In each of them, they first studied a list of house pictures. Then they went through a recognition test with revelation tasks prior to half of the probe items followed. For each block, the same item material was used. Thus, participants learned the items frequently and consequently the number of extra-list items increased. To sum it up, I implemented a 3 (frequency: block) x 2 (test position: intact vs. revealed) x 2 (item type: target vs. distractor) factorial within design and observed the proportion of "old"-responses. I expected the following results:

1. Targets should be judged "old" more often than lures.

2. A negative revelation effect should occur in the first block.

3. The magnitude of the negative effect should decrease with the number of blocks.

2.2 Sample

In total, 60 people participated in the experiment. I dropped one person because the computer shut off during the experiment. Moreover, I excluded seven participants from further analysis because their proportion of correct responses was not significantly above chance level. In the remaining sample, 19 participants were male, 33 female. They were between 19 and 63 years old (*M* = 23.5, *SD* = 6.8). Most of the participants studied psychology (*n* = 27). Furthermore, I included 13 students of business administration/economics/law, three students of humanities, one social sciences student, four students who study something else than the mentioned subjects and four participants not studying. Most of them (*M* = 94.2 %) spoke German as mother tongue. Participants were rewarded with course credits and sweets.

2.3 Material

The material consisted of nine photos for the test trial and 80 photos of houses for the main part of the experiment, retrieved from *flickr.com* (see Appendices A and B). All presented houses had a pointed roof. Pictures were all cut to the same size (600 x 450 pixels). To reduce similarity to pictures that participants might have seen in property magazines or the like – which would serve as extra-list items – the photos were presented in black and white (see Appendix B).

Figure 4. Left: example for a randomly scrambled version of an item. Participants had to solve the puzzle by dragging the pieces to the right place. Right: unscrambled picture, used for the subsequent recognition test.

2.4 Procedure

All instructions were given in German. Participants signed a form of informed consent and then started with the experiment on a Mac mini® computer. Then, participants read the instructions and ran through a test trial, consisting of a short version of the following experiment. For the test trial, different pictures than houses were used (see Appendix A). After the test trial, the first block started. Participants studied 40 randomly chosen houses of the 80 pictures in the item pool. Each house appeared for 2.5 s. Afterwards, the screen turned black for 200 ms, then the next item appeared. After the study phase, a filler task followed for approximately 30 s: Participants had to decide if a simple mathematical equation was correct or false. Subsequently, the recognition test started. Participants were asked to decide whether they had studied an item before (“old”) or not (“new”). For this, they clicked on an “old” or “new” button on the screen with the curser. Fifty percent of the probes, selected randomly, appeared in a disguised way in form of a puzzle task. For this purpose, the picture was cut into nine (3 x 3) pieces and scrambled randomly (see Figure 4). Participants could solve the puzzle by dragging a piece and dropping it at a new position. Then, the dropped piece and the piece that formerly had been at the new position swapped places automatically. When the participants had solved the puzzle task, they were automatically forwarded to the recognition question. All 40 studied items served as targets in the test. The remaining 40 items occurred as lures. Thus, the test included all 80 pictures. After the recognition test, participants took a break for 60 s. Then the next block started. All three blocks had exactly the same design, but for each block, items were independently and randomly selected as targets or lures. Besides, item order was random and independent for every block.

2.5 Results

None of the participants struggled with solving the puzzle tasks. On average, they needed 7515.23 ms for the task (*Mdn* = 6532 ms; *SD* = 1688.47). Mean response time for the recognition task was 2701.57 ms (*Mdn* = 2173.00 ms; *SD* = 599.25). The rate of correct responses in the recognition task was 68.8 % (*SD* = 6.0). An ANOVA with the percentage of correct responses in the recognition test as the dependent variable was conducted. Surprisingly, performance did not decrease over the three blocks. Instead, there was a highly significant improvement of answering accuracy, $F(2, 102) = 9.73$, $p < .001$, $\eta^2 = .16$, indicating that the motivation of participants stayed up over all three blocks (M_{Block1} = 65.31 %; M_{Block2} = 69.33%; M_{Block3} = 71.61%).

At a base rate of 50 % targets and 50 % lures, on average 49.8 % (*SD* = 9.0) were “old”-responses. Table 1 depicts the proportion of “old”-responses, separately for block, test position and item type. A 3 (block) x 2 (test position: intact vs. revealed) x 2 (item status: lure vs. target) factorial within subjects ANOVA with the rate of “old”-answers as dependant variable was conducted. There was a main effect of test position, $F(1, 51) = 23.86$, $p < .001$, $\eta^2 = .319$, indicating that a negative revelation effect occurred (M_{Intact} = .53; $M_{Revealed}$ = .47). Moreover, I found a significant main effect of the block, $F(2, 102) = 3.92$, $p = .023$, $\eta^2 = .071$, showing that the proportion of “old”-answers increased with the block number (M_{Block1} = .48; M_{Block2} = .49; M_{Block3} = .52). And a highly significant main effect of item status appeared, $F(1, 51) = 505.3$, $p < .001$, $\eta^2 = .908$, indicating that targets were more often judged to be “old” than lures (M_{Lures} = .31; $M_{Targets}$ = .69). These main effects were qualified by the following significant interactions: there was a significant interaction between block and test position, $F(2, 102) = 3.61$, $p = .031$, $\eta^2 = .066$, and a highly significant interaction between block and item status, $F(2, 102) = 9.73$, $p < .001$, $\eta^2 = .160$, as well as between test position and item status, $F(1, 51) = 15.60$, $p < .001$, $\eta^2 = .234$. The interaction between block, test position and item status was not significant, $F(2,102) = 1.43$, $p = .24$. To get a better conception of the data, further two ANOVAs were conducted, separately for lures and targets (see Figure 5).

Table 1

Percentage of "old" responses (standard error of mean in parentheses) by block, test position and item type.

		Item Type		
Block	**Test Position**	Lure	Target	Total
1	Intact	.35 (.02)	.69 (.02)	.52 (.02)
	Revealed	.30 (.02)	.57 (.02)	.44 (.02)
	Total	.33 (.02)	.63 (.02)	.48 (.01)
2	Intact	.30 (.02)	.73 (.02)	.51 (.02)
	Revealed	.30 (.02)	.65 (.03)	.47 (.02)
	Total	.30 (.02)	.69 (.02)	.49 (.02)
3	Intact	.32 (.02)	.76 (.02)	.54 (.02)
	Revealed	.29 (.03)	.71 (.02)	.50 (.02)
	Total	.30 (.02)	.74 (.02)	.52 (.02)
Total	Intact	.32 (.02)	.73 (.01)	.53 (.01)
	Revealed	.30 (.02)	.64 (.02)	.47 (.01)
	Total	.31 (.02)	.69 (.01)	.50 (.01)

Note. Standard errors could be adjusted for the within subjects design (see Loftus & Masson, 1994). Adjusting could lead to smaller standard errors.

In the 2 x 2 ANOVA for lures, there was neither a significant main effect of block, $F(2, 102) = .75$, $p = .474$, nor a main effect of test position, $F(1, 51) = 3.93$, $p = .053$. Nor the interaction was significant, $F(2, 102) = 1.56$, $p = .216$. To sum it up, no revelation effect occurred for lures. In the 2 x 2 ANOVA for targets, a highly significant main effect of test position appeared, $F(1, 51) = 35.60$, $p <.001$, $\eta^2 = .411$, showing the occurrence of a negative revelation effect ($M_{Intact} = .73$; $M_{Revealed} = .64$). The main effect of block was also highly significant, $F(2, 102) = 16.86$, $p < .001$, $\eta^2 = .248$ ($M_{Block1} = .63$; $M_{Block2} = .69$; $M_{Block3} = .74$). Furthermore, I observed a significant interaction between block and test position, $F(2, 102) = 3.48$, $p = .035$,

η^2 = .064. To further explore how the magnitude of the effect changes with the block, I conducted a polynomial contrast analysis for the interaction between block and test position. This resulted in a highly significant linear trend, $F(1, 51) = 7.89$, p[1] =.007, η^2 = .134. Additionally, a quadratic trend did not appear, $F(1, 51) = .009$, $p = .926$.

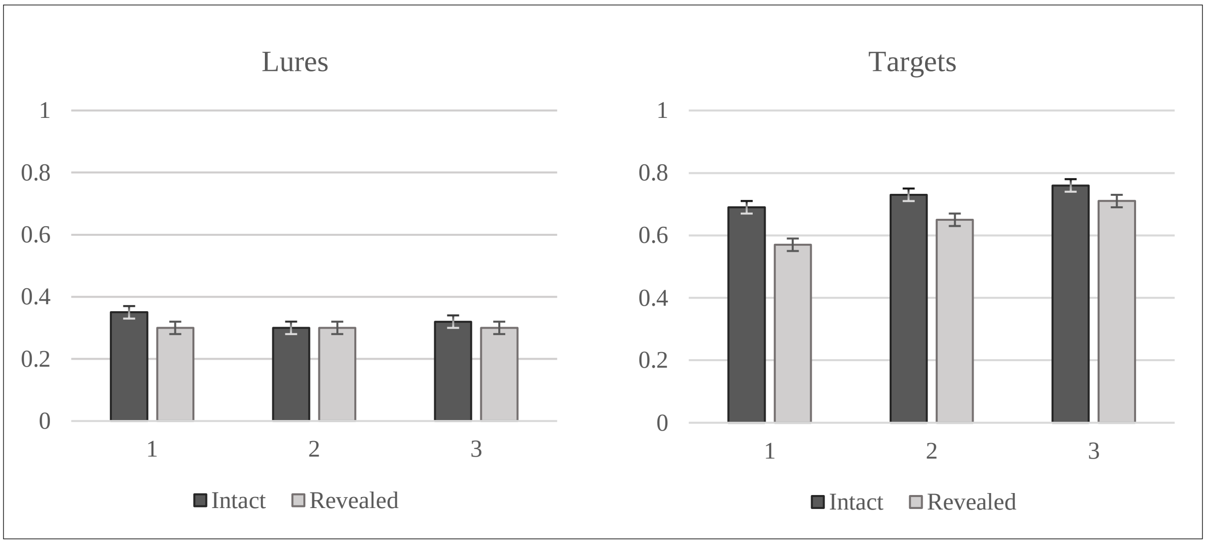

Figure 5. Proportions of “old”-responses, separately for lures and targets. For targets, there is a significant main effect for block and for test position and a significant interaction between block and test position. Error bars represent the standard errors of the means. Please note that standard errors can be adjusted for the within subjects design (see Loftus & Masson, 1994).

To sum it up, the results of this analysis exactly comply with the hypotheses, that is, the predictions of MINERVA II. Thus, a negative revelation effect was found for targets. This corresponds with findings in literature which show that the negative revelation effect more likely occurs for targets (e.g., Zaiser, 2015; Aßfalg & Bernstein, 2012, Experiment 2) and the positive effect for lures (Hicks & Marsh, 1998). The magnitude of the negative effect can be seen as the difference between the proportion of “old”-responses in the intact condition and the revelation condition. The difference decreases with the block, and the contrast analysis shows that this is a highly significant linear trend. Thus, the magnitude of the negative revelation effect decreases with the increasing number of extra-list items.

[1] It should be noted that the p-value of the linear contrast could be halved because the hypothesis about the trend over the three blocks was a directional hypothesis.

3 Discussion

In the present study, I further investigated the occurrence of a negative revelation effect. According to MINERVA II, the revelation effect is caused by a loss of contextual information of the probe due to the preceding revelation task. The reversed effect should appear for low frequency material, or spoken in terms of MINERVA II, for item material with few matching extra-list items. In the experiment I used pictures of houses as low frequency material and expected to find a negative revelation effect in the first block. In order to increase frequency, participants reiterated the experiment three times with the same item material (factor block). If MINERVA II is proven right, the effect should get more positive, that is, the magnitude of the negative effect should decrease. The data of the experiment reflects all these predictions: firstly, the findings of Aßfalg and Bernstein (2012) could be replicated with different stimulus material. In their study, the authors used faces which had to be revealed in a puzzle task. The result of a negative effect was quite unexpected for them. In a post-hoc discussion, Aßfalg and Bernstein attributed the findings to the rather uncommon stimulus material. Thus, they argued that faces were processed holistically and the puzzle task disturbed this way of processing. In the present study, I could rule out this explanation by using houses as stimulus material. Secondly, I found a linear trend of a decreasing negative effect for targets over the three blocks. These results reinforce the frequency approach of MINERVA II in a manner never shown before. Further research should pursue experimental designs with manipulations of extra-list items. For instance, the effect could reverse from a negative to a positive effect when low frequency material is used and frequency increased to an even greater extent than in my study.

Nevertheless, it remains unclear why Bornstein and Wilson (2004) found a positive revelation effect with face material. It has to be noted that the revelation task consisted merely of attractiveness ratings. This task is rather easy and participants know that they cannot give a wrong answer because attractiveness ratings are totally subjective. Thus, the task might not be difficult enough to force participants to really focus on it and consequently neglect the context information. Additionally, research has shown that attractiveness ratings per se increase face familiarity (e.g., Shearer & Mikulka, 1996). Both objections together might explain the occurrence of a positive revelation effect for faces.

In their meta-analysis, Hicks and Marsh (1998) found that the positive revelation effect is more likely to occur when analysing lures than targets. However, it seems to be more likely to find the negative revelation effect when focusing the analysis on targets (e.g., Zaiser, 2015; Aßfalg & Bernstein, 2012, Experiment 2). The present experiment is consistent with these findings. Even though none of the theories discussed so far provides an explanation for it, simulations of MINERVA II reflect this pattern when modelling changes in frequency. Nonetheless, the underlying processes remain to be revealed.

Generally, the revelation effect only occurs for recognition judgements that base on episodic memory. According to MINERVA II, context information of the recognition item is needed for the recognition tasks. But encoding of the context is disrupted by the preceding revelation task. However, for semantic decision tasks, the context information is not necessary either. Hence, the revelation effect does not appear for semantic tasks like lexical judgements or frequency estimations (e.g., Watkins & Peynircioglu, 1990). However, Bernstein, Whittlesea and Loftus (2002) found a marginal revelation effect for general knowledge judgements. For example, participants had to decide whether a *leopard* was the *fastest animal in the world*. Prior to half of the answers (“true” vs. “false”), an anagram task was interpolated. In fact, this finding contradicts MINERVA II. Yet it should be noted that the procedure of the experiment was rather uncommon: Participants first read the general statement, then solved the revelation task and finally judged whether the statement was true or false. It is conceivable that the statement itself, when not presented directly prior to the retrieval question, might lead to an extra representation in memory. This secondary process could explain small revelation effects. Needless to say that this post-hoc approach is not sufficient to explain the outcome of the experiments of Bernstein et al. (2002). The influence of the experimental order in episodic and semantic memory designs should be the subject of future research.

The secondary process mentioned above could also be the reason for the findings of Borstein et al. (2015). In their experiment, they analysed the role of the semantic relatedness between the revelation item and the probe. In fact, they used the standard procedure (c.f. Watkins & Peynircioglu, 1990, Experiment 1), but in their design they manipulated the relatedness between revelation item and probe (same item vs. semantically related vs. semantically unrelated vs. no revelation task). They found a significant linear trend of semantic relatedness for false alarms, being most likely in the same item condition. Similar to the discussion about the findings in general knowledge judgements, in this case a secondary process might be the cue too. Thinking in MINERVA II’s terms, the revelation item itself might be encoded and stored as a vector after solving it. Afterwards it represents another extra-list item with approximately the same context and more or less the same item features as the probe. This could have a small but observable influence on the recognition task. But again, it should not be relied on this explanation without examining the predictions of this assumption.

In the past decades, research on recognition memory has faced a number of memory distortions, such as the list-strength effect (see Clark & Gronlund, 1996), the list-length effect (e.g., Strong, 1912) or similarity effects (Tulving, 1981), to mention only a few. The broad variety of phenomena brought forward a large number of memory models. Attempts to build up a framework in order to explain all of them with one single model have been rare (see also Brandt, 2007). Being rather neglected in the past few years, Global Memory Models have certainly not yet been examined exhaustively. But they offer a comprehensive framework to many of the findings of previous research, including aspects in which other approaches offer only limited insights. A great advantage of MINERVA II is the formality of the approach. Every factor like frequency, list homogeneity, list length or context encoding can be included in a computer simulation. Calculating the exact impact of these factors and of the interactions of the factors might sometimes go beyond our cognitive capacities. But in the simulations we might model them and derive exactly quantifiable predictions. Such an approach should be appreciated when it comes to an effect that is highly elusive like the revelation effect.

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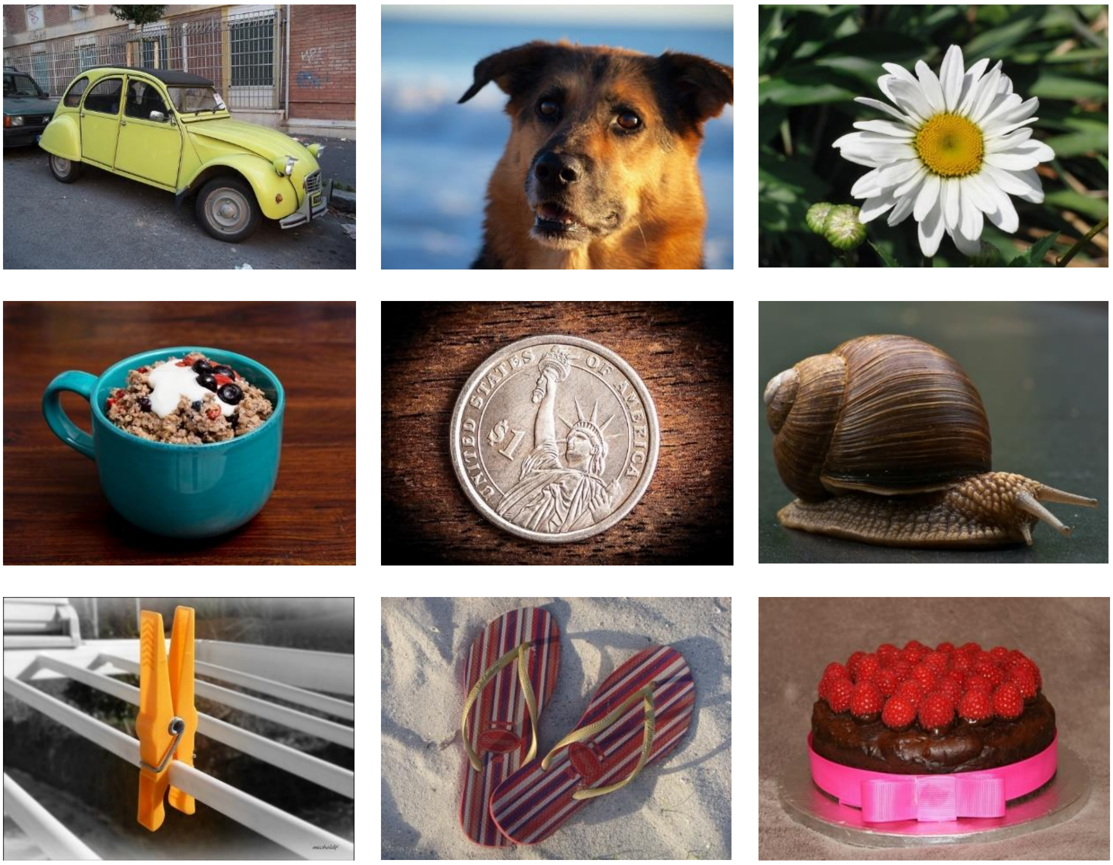
Appendix

Appendix A. *Item material for the test trial.*



Appendix B. *Item material for the recognition test (block 1 to 3).*















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