# Emotional Source Memory:
# (When) Are Emotional Sources Remembered Better?

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For mom

Для мамы

♡

*As knowledge increases, wonder deepens.*

– Charles Morgan

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# Summary

Emotional information benefits memory. This phenomenon of emotion-enhanced memory (EEM) has been well established for item memory (i.e., memory for central information) but poorly investigated for source memory (i.e., memory for the context of information). Filling this research gap, I examined in the following dissertation whether and under which conditions source memory is better for emotional (versus neutral) sources by focusing on three potential influencing factors: Valence and arousal of sources, aging, and encoding instructions. In all three manuscripts, source stimuli were selected based on normative valence and arousal ratings, thus ensuring an effective emotionality manipulation. Item stimuli were neutral and unrelated to the source material. In all manuscripts, the methodological approach followed the standard source-monitoring paradigm, and analyses of source-monitoring data were based on multinomial modeling.

Manuscript 1 revealed that there is no beneficial effect of source valence or source arousal on source memory. Manuscript 2 indicated that only younger but not older adults show enhanced source memory for emotional (i.e., positive and negative) compared to neutral sources. Thus, Manuscript 2 showed a valence effect in source memory which, however, was absent in Manuscript 1. Clarifying this inconsistent result pattern, Manuscript 3 unveiled that EEM effects in source memory depend on the encoding instructions: EEM effects robustly occur if an affective orienting, item-focused task is used during item-source encoding (as in Manuscript 2) but do not occur if no such orienting task is used (as in Manuscript 1). In sum, the overall results clearly indicate that emotional sources per se are not remembered better. Instead, an affective item-source processing seems crucial for establishing EEM effects in source memory. With this, my thesis identifies important boundary conditions that foster versus hinder EEM effects and thus contributes to a better understanding of how emotion influences episodic memory.

# Manuscripts

This dissertation answers the question of whether and when emotional sources benefit source memory by focusing on three different factors: Valence and arousal of sources (Manuscript 1), aging (Manuscript 2), and encoding instructions (Manuscript 3). Manuscript 1 and Manuscript 2 are published, Manuscript 3 is submitted for publication in *Cognition and Emotion*. The research conducted in this dissertation has been supported by the Research Training Group "Statistical Modeling in Psychology" (SMiP), funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation).

In the main text of this thesis, I provide a brief review of previous research on emotional source memory, describe the methodological approach used in this dissertation, give an overview of the three manuscripts, and conclude by discussing the strengths and weaknesses of this research as well as potential future directions. For specifics about the experimental procedures and statistical analyses used in the manuscripts, please refer to the original manuscripts appended to this thesis.

**Manuscript 1**

Symeonidou, N., & Kuhlmann, B. G. (2022). Better memory for emotional sources? A systematic evaluation of source valence and arousal in source memory. *Cognition and Emotion*, *36*(2), 300-316. https://doi.org/10.1080/02699931.2021.2008323

**Manuscript 2**

Symeonidou, N., Hassan, A., Porstein, I. & Kuhlmann, B. G. (2022). Is there an emotionality effect in older adults' source memory? *Aging, Neuropsychology and Cognition*. Advance online publication. https://doi.org/10.1080/13825585.2022.2078778

**Manuscript 3**

Symeonidou, N., & Kuhlmann, B. G. (2022). *Enhanced source memory for emotional sources: Does an affective orienting task make the difference?* Manuscript submitted for publication.

# 1 Introduction

If you take a moment to remember the first time you drove a car or your last day at school, you might be surprised by the vividness of your memory. Emotional memories are almost like snapshots of previous live events, characterized by a high richness of details, vividness, and accuracy (Kensinger, 2009; Kensinger & Schacter, 2008; Rimmele et al., 2011). Their fascinating nature has stimulated a great bulk of research investigating how emotional memories shape our autobiographic memory (Brown & Kulik, 1977), contribute to trauma development (Holmes & Bourne, 2008), bias eyewitness testimonies (Loftus et al., 1987), influence false memories (Pesta et al., 2001) and many more. To systematically investigate the basic mechanisms behind the phenomenon of emotion-enhanced memory (EEM), researchers have used emotional (versus neutral) items (e.g., words or pictures) in their studies and tested whether and why memory is enhanced for these emotional (versus neutral) items (Kang et al., 2014; Libkuman et al., 2004; Phelps, 2004; Talmi & McGarry, 2012). Locating emotional stimuli on two emotionality dimensions, valence (negative versus positive) and arousal (calming versus activating; see circumplex model by Russell, 1980), these studies have identified important cognitive-behavioral and neural-affective mechanisms underlying valence-based and arousal-based EEM effects, respectively (see Kensinger & Schacter, 2008; Mather, 2007; Talmi, 2013 for reviews).

Interestingly, this research has reliably established EEM effects in item memory, that is, memory for centrally presented stimuli (Glisky et al., 1995), such as pictures or words, but neglected to investigate EEM effects in source memory in the same systematic manner. Source memory refers to remembering the contextual details of an experienced event, for example, its location, its time of day, other persons involved, and so on (Johnson et al., 1993; Mitchell & Johnson, 2009). It is so far unclear whether such contextual features are remembered better if they have an emotional value. Put differently, there has been no or very little systematic research on whether and when source memory is enhanced for emotional (versus neutral) source features (but see Bell & Buchner, 2012). This research gap is surprising considering that episodic memories are often marked by such emotional context features, for example, when we remember receiving information from a likable or dislikable person or when we remember walking home in a severe storm or spectacular sunset. Such emotional context features can determine the emotionality of the whole experience, thereby shaping how the event is represented in episodic memory. Thus, a shift in research focus from item emotionality to source emotionality would contribute to a more holistic understanding of how emotion influences episodic memory. Although some researchers have already begun to

investigate memory for emotional source features (Bell & Buchner, 2012; May et al., 2005; Ventura-Bort et al., 2017), this research mostly lacks a common methodological ground and has yielded inconsistent results.

Considering all this, the goal of this dissertation was to systematically investigate whether and under which conditions source memory is enhanced for (inherently) emotional compared to neutral sources. All studies encompassed in this dissertation relied on the same methodological approach, which was specifically tailored to the investigation of emotional sources. I will first give a brief overview of the research conducted so far on emotionality and source memory before describing the methodological approach. I will then turn to the central findings of the three manuscripts and conclude by discussing their implications for future research whilst considering the strength and limitations of this dissertation.

# 2 Emotionality and Source Memory

If you again recall your memory of your first car drive, you might realize that its high vividness is the result of recollecting the small contextual details of this event (e.g., the time of day, the color of the car, your driving instructor). The ability to remember all these (e.g., temporal, spatial, social) details of an experience has been termed source memory (Johnson et al., 1993). While previous research has established a robust emotion-enhanced memory effect for item memory (i.e., memory for central information; e.g., Kensinger, 2007; Talmi, 2013), the research on emotion and source memory has been rather inconclusive. When reviewing this literature, it is important to differentiate between two lines of research (cf., Bell, Buchner, Erdfelder et al., 2012):

1) Studies that investigated the effects of *emotional items* on source memory. These studies used neutral sources and manipulated *item emotionality*.
2) Studies that investigated the effects of *emotional sources* on source memory. These studies used neutral items and manipulated *source emotionality*.

In the following review, I will briefly summarize the findings on item emotionality (research line 1) but mostly focus on source emotionality (research line 2), as this research mainly motivated the rationale of this dissertation.

## 2.1 Effects of Item Emotionality on Source Memory

Most of the research on emotionality and source memory can be classified under research line 1, that is, it has focused on the effects of emotional (versus neutral) items on source memory for neutral source features. Taken together, the results of these studies suggest that source memory is enhanced for intrinsic source features of emotional items (e.g., the font color of emotional word items, Doerksen & Shimamura, 2001) versus reduced for external source features of emotional items (e.g., frame color of emotional picture items, Boywitt, 2015; see Chiu et al., 2013 for a review of studies). This is in line with the prevalent belief that emotional items draw focused attention. This attentional bias leads to enhanced memory for the emotional item and its central/intrinsic features (i.e., EEM effect) but reduced memory for all other peripheral/external information (so-called emotion-induced memory trade-off; see Kensinger, 2009; Levine & Edelstein, 2009; Mather, 2007). Although there are still findings that are not in line with this influential central-peripheral trade-off account (see

Chiu et al., 2013; Mather & Sutherland, 2011 for overviews), the question of how item emotionality influences source memory (and associative memory more generally) has enjoyed a continuous research interest, leading to comprehensive, nuanced, still to-be-tested accounts on emotion and memory, which go beyond the scope of this dissertation (e.g., Bisby & Burgess, 2013; Mather & Sutherland, 2011). In contrast and somewhat surprisingly, the research on whether and how emotional sources influence source memory (research line 2) is rather sparse and unsystematic.

## 2.2 Effects of Source Emotionality on Source Memory

The few studies that manipulated source emotionality considerably vary in their research goals and thus in their methodological approach. When reviewing these studies, I will first focus on whether they show an *EEM effect in source memory*, that is, enhanced source memory for emotional over neutral sources (also referred to as *source emotionality effect* in the following). I will then highlight the main differences across these studies and thus derive the rationale behind the three manuscripts which constitute this dissertation.

One of the first who studied emotional sources was the research group around Bell et al. (starting with Buchner et al., 2009; see Bell & Buchner, 2012 for a review). They investigated whether source memory is enhanced for (contextual) behavioral information that signals cheating (versus trustworthy) behavior. For example, Bell and Buchner (2010) presented neutral faces (=items) with descriptions of cheating versus trustworthy behavior (=sources) to participants and instructed them to rate the likability of the face items during encoding (i.e., affective orienting task). Across several studies (Bell & Buchner, 2010, 2011; Bell, Buchner, Erdfelder et al., 2012; Buchner et al., 2009), the authors found that participants' source memory was enhanced for cheating (i.e., socially threatening) compared to trustworthy sources. Extending these results to descriptions of other negative (non-cheating) behavior, the authors later argued that the negative valence of sources and expectancy violation (instead of social threat specifically) underlies these source-memory enhancements (Bell & Buchner, 2010; Bell, Buchner, Kroneisen et al., 2012). However, the unique contribution of (negative) valence versus arousal to source emotionality effects remained an open question.

Emotional sources have also been examined in aging research. For example, focusing on age-related changes in socio-emotional processing, May et al. (2005) and Rahhal et al. (2002) showed that older adults benefit more from emotional sources compared to younger adults. In these studies, the authors used neutral sources and, via instructions, related these neutral sources to the concept of threat (May et al., 2005) or falsehood (Rahhal et al., 2002).

For example, participants were told that food (=items) presented left versus right (=source) were safe versus dangerous (May et al., 2005) or that statements (=items) spoken by voice A versus voice B (=source) were lies or true statements (Rahhal et al., 2002). Results suggested that older adults' source memory was better if the source was tied to an emotional concept (e.g., items' safety) while younger adults did not show such enhancements. In contrast, using sentences (=items) spoken by voices with a neutral or emotional tone (=sources), Davidson et al. (2006) showed that older adults benefit *less* (instead of more) from emotional sources than younger adults. Thus, results are overall inconclusive, and it remains unclear whether and how source emotionality effects differ between older and younger adults.

Finally, emotional sources have been also used in neuropsychological studies to investigate the neural dynamics underlying memory for (neutral) items that occur in such emotional (versus neutral) contexts. Interestingly, these studies often applied perceptual (instead of conceptual) emotional material as sources. For example, Ventura-Bort, Löw, Wendt, Moltó et al. (2016) presented neutral objects superimposed on emotional (positive and negative) or neutral scene pictures and instructed participants to imagine the objects as part of the scene (i.e., mental imagery instructions). Results indicated that source memory was better for emotional compared to neutral source pictures (see also Smith et al., 2004; Smith et al., 2005, for similar procedures and results). In contrast, Schellhaas et al. (2020) presented neutral faces (=items) in different background colors (=sources), which either signaled threat of electric shock or safety. Although neural processes at retrieval differentiated between faces encoded in a threatening versus safe context, participants' source memory did not differ between threat-of-shock versus safe contexts (see also Arnold et al., 2021, for similar behavioral results). Importantly, these neurological studies do not only differ in how source emotionality was manipulated (i.e., emotional pictures versus threat-of-shock instructions), but they also differ in their encoding instructions. While Ventura-Bort, Löw, Wendt, Moltó et al. (and Smith et al., 2004) told participants to imagine a link between items and sources, no such instructions were used in Schellhaas et al. (or Arnold et al., 2021). Notably, such variations in encoding instructions also occur in the above-reviewed behavioral research. For example, Bell and Buchner have typically used an affective orienting task during encoding (e.g., likability ratings, Bell & Buchner, 2010), while May et al. (2005) and Rahhal et al. (2002) used intentional item and source encoding instructions. As encoding instructions can substantially alter how items and sources are linked and stored in memory (e.g., Diana et al., 2008), they might also modulate source emotionality effects. Put simply, encoding instructions might be

another important factor that needs to be considered to understand the inconclusive findings on EEM effects in source memory.

This short review already shows the considerable variation across studies in the main substantive focus (e.g., cognitive aging versus neural dynamics), in the material used for the source emotionality manipulation (e.g., conceptually versus perceptually emotional stimuli), and in the instructions used for item-source encoding (e.g., affective orienting tasks versus mental imagery instructions). Building on this, this dissertation systematically tackled these differences as they might explain the diverging results of previous studies. More specifically, the three manuscripts answer the following questions:

*Manuscript 1:* Is source memory indeed enhanced for emotional sources? How do source valence and source arousal contribute to such enhancement effects?

*Manuscript 2:* Do source emotionality effects differ between older versus younger adults? That is, do older adults profit more or less from emotional compared to neutral sources?

*Manuscript 3:* Can encoding instructions influence source emotionality effects? That is, do source emotionality effects occur only when certain types of instructions are used?

Of note, while both emotionality dimensions (source valence and arousal) were manipulated in Manuscript 1, the research questions in the other two manuscripts required a focus on source valence only (holding source arousal constant); see section 4 for more details. Further crucially, to exclude that variations in results are confounded with variations in method, it was first important to set up a joint methodological approach, which was tailored to the investigation of emotional sources. More specifically, all studies relied on the standard experimental paradigm to investigate source monitoring (Johnson et al., 1993; see next section). Additionally, great care was taken to select stimuli for the source emotionality manipulation. Details of this methodological approach are described next.

# 3 General Methodological Approach

All studies included in this thesis share three main methodological aspects: First, the experimental procedure followed the standard source-monitoring paradigm (Johnson et al., 1993), which is specifically tailored to the investigation of source-monitoring processes. Second, multinomial modeling (Bayen et al., 1996) was used to derive source memory (and item memory) measures that are corrected for guessing bias. Third, perceptually emotional material was used to manipulate source emotionality. The material was carefully selected based on normative valence and arousal ratings.

## 3.1 The Standard Source-Monitoring Paradigm as General Procedure

Source monitoring encompasses all processes that are involved when we reconstruct the source (i.e., origin) of an experience, including source memory (Johnson et al., 1993; Kuhlmann et al., 2021). That is, to make a source attribution, people do not only rely on the actual recollection of source features but additionally use their general knowledge and beliefs. For example, if you recall your driving-memory again, you might remember regretting that you put on your flip-flops that day. From this, you might then reconstruct that the driving event must have taken place on a warm, sunny day.

These processes of source memory and reconstruction are also at play when we look at source attributions in the experimental setting. In the standard source-monitoring paradigm, which was used in this dissertation, participants first study multiple items that are presented with either one of two (or three) sources. For example, participants might study words (=items) that are paired with one of three pictures (=sources), see Figure 1. Then in the test phase, all studied items plus some new items (i.e., distractors) are presented, and participants are asked to make a source judgment. For example, as can be seen in Figure 1, participants have to decide whether the word was originally presented with the negative, positive, or neutral picture or whether the word is new. Thus, in the standard paradigm, the item information varies from trial to trial, while the sources repeat across trials, meaning that one source is paired with several items (so-called *many-to-few mapping* of items to sources; Glisky et al., 2001; Kuhlmann et al., 2021). Crucially, a correct answer in the source-monitoring test can be based on actual recollection (i.e., source memory) or a lucky guess (i.e., source guessing).

To disentangle memory and guessing processes in this standard paradigm and thus derive separate measures for source memory and source guessing, Bayen et al. (1996) formulated and empirically validated the so-called *two-high-threshold multinomial model of*

*source monitoring* (2HTSM). Generally speaking, multinomial models are binary stochastic models for discrete categorical data (Erdfelder et al., 2009). They are often applied in cognitive psychology to dissociate different cognitive processes that lead to the same empirical observation (e.g., correct assignment of an item to its source) by estimating the probability of each of these underlying processes. The 2HTSM builds on the assumption that item and source memory are discrete (all-or-none) processes (Bayen et al., 1996). This assumption is opposed to the view that memory is a graded process and relies on a continuous strength signal (Wixted, 2007). Notably, the discrete versus continuous account result in alternative approaches to model item and source memory (e.g., 2HTSM versus [bivariate] signal detection model; DeCarlo, 2003). In fact, there is an ongoing debate on whether memory can be best described as a discrete or continuous process. However, the current state of evidence suggests that source memory is a discrete, threshold-like process (Zhou et al., 2021), whereas item memory relies on a continuous signal (Kellen et al., 2021; see also Yonelinas, 2002). As the focus of my dissertation is on source memory, the 2HTSM was a reasonable choice for modeling the source-monitoring data.

The 2HTSM assumes that source judgments in the standard source-monitoring paradigm are driven by four processes: Item recognition (parameter *D*), source memory (parameter *d*), item old/new guessing (parameter *b*), and source guessing (parameter *g*). The source-memory results reported in all three manuscripts refer to the source-memory parameter *d*. Note that the original model was designed for a paradigm that implements two sources in the study phase (Bayen et al., 1996). As, however, in all studies of this thesis, three source types were used, an extended version of this model was applied for data analysis (Keefe et al., 2002). This extended version is illustrated in Figure 2. The software multiTree (Moshagen, 2010) was used to estimate model parameters based on the aggregated observed response frequencies in the source-monitoring test (aggregated across participants and items). MultiTree was also used to evaluate model fit via maximum likelihood estimation methods.

Further note that the 2HTSM formed the basis for conducting a priori power analyses in all studies of this dissertation. More specifically, differences across source memory parameters *d* (e.g., the difference between source memory for emotional sources $d_{emotional}$ and source memory for neutral sources $d_{neutral}$) entered the power analysis as effects of interest. Thus, the sample size in each experiment was a priori tailored to reliably detecting source memory differences of a certain size (with $\alpha = .05$ and $1-\beta = .80$). Details on these power analyses can be found in the original manuscripts.

## 3.2 Selection of Emotional Stimuli

Normed emotional stimuli were used to manipulate source emotionality in all studies of this dissertation. More specifically, building on the above-described neuropsychological studies (e.g., Smith et al., 2004), we opted for perceptually emotional material (e.g., pictures) because it has been shown to be more emotionally charged compared to semantically emotional material (e.g., words; Bayer & Schacht, 2014; Kensinger & Schacter, 2006). With this, we provided a stronger source emotionality manipulation compared to most of the behavioral studies on source emotionality, which typically applied semantically (e.g., Buchner et al., 2009) or conceptually emotional (e.g., May et al., 2005) material. The use of normed material did not only ensure a certain effectiveness of the emotionality manipulation but also allowed for a systematic variation and/or control of the two prevalent emotionality dimensions, valence and arousal. For Experiment 1 of Manuscript 1, sounds were drawn from the *International Affective Digitized Sounds* (IADS) database (Bradley & Lang, 2007) and used as source stimuli (e.g., the sound of a siren, a train, or rock & roll music). For all remaining experiments, pictures drawn from the *Open Affective Standardized Image Set* (OASIS; Kurdi et al., 2017) were used as sources (e.g., pictures of a garbage dump, a car race, or a lake; see Figure 1).

Following the standard source-monitoring paradigm, only a small number of stimuli (usually three stimuli) were selected to function as sources (see Experiment 2 of Manuscript 2 for an exception). For example, the negative source was operationalized via one or two negative pictures. These stimuli were selected based on their original norm ratings. Notably, to ensure that the stimuli were indeed emotionally effective, their original ratings were additionally checked in one of the two following ways: 1) Valence and arousal ratings for the used source stimuli were either post-hoc collected at the end of the respective experiment (i.e., manipulation check) or 2) a pre-study was conducted in which valence and arousal ratings for a reasonable pre-selection of potentially suitable stimuli were collected. Then, based on these pre-study ratings, the final source stimuli for the main study were chosen. Either way, it was ensured that the source stimuli had the intended emotionality in all studies.

Unlike the source material, items (pictures in Experiment 1 of Manuscript 1, words in all remaining experiments) were neutral in valence and low in arousal. Further importantly, sources and items were chosen in such a way that there was no inherent relation between both (e.g., words as items and unrelated pictures as sources). Thus, sources were unlikely to be processed as an intrinsic feature of the item. This ensured that items and sources were clearly distinguishable and emotionality effects on item versus source memory could be separated. Note that this was not always the case in previous studies outlined above, which have

often used highly relatable item-source material (e.g., faces [=items] with descriptions of cheating behavior [=sources] can be processed as cheaters; Bell & Buchner, 2010), or instructed participants to process items and sources as a unit (e.g., imagine the object [=item] as part of the scene image [=source]; Ventura-Bort, Löw, Wendt, Moltó et al., 2016). Such material and instructions blur the distinction between item and source (Diana et al., 2008) and thus make it difficult to disentangle source versus item memory effects. Further importantly, incidental source learning was applied in all studies of this dissertation. This means that participants' attention was not explicitly guided towards the sources, and thus EEM effects in source memory could unfold rather spontaneously. Both the use of external (item-unrelated) sources and the use of incidental source learning served the goal of investigating whether emotional sources *per se* (independent of the item) influence source memory.

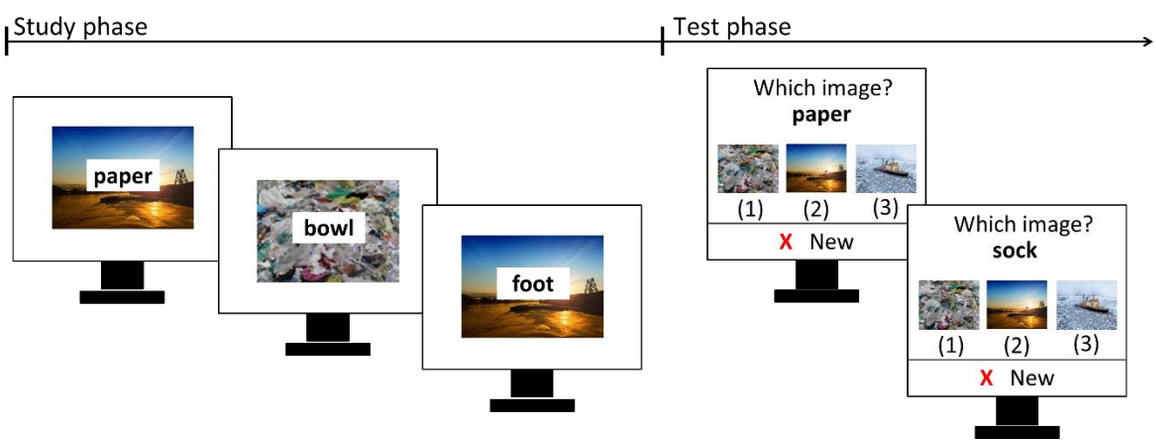


**Figure 1.** Schematic illustration of the standard source-monitoring paradigm with words used as items and three pictures used as sources (two emotional and one neutral picture, drawn from the *Open Affective Standardized Image Set* [OASIS]; Kurdi et al., 2017). Items vary from trial to trial whereas sources repeat across trials, resulting in a many-to-few mapping of items to sources. Note that this type of item material (i.e., words) and source material (i.e., pictures) was used in Experiment 2 of Manuscript 1 and in both experiments of Manuscript 2 and 3.

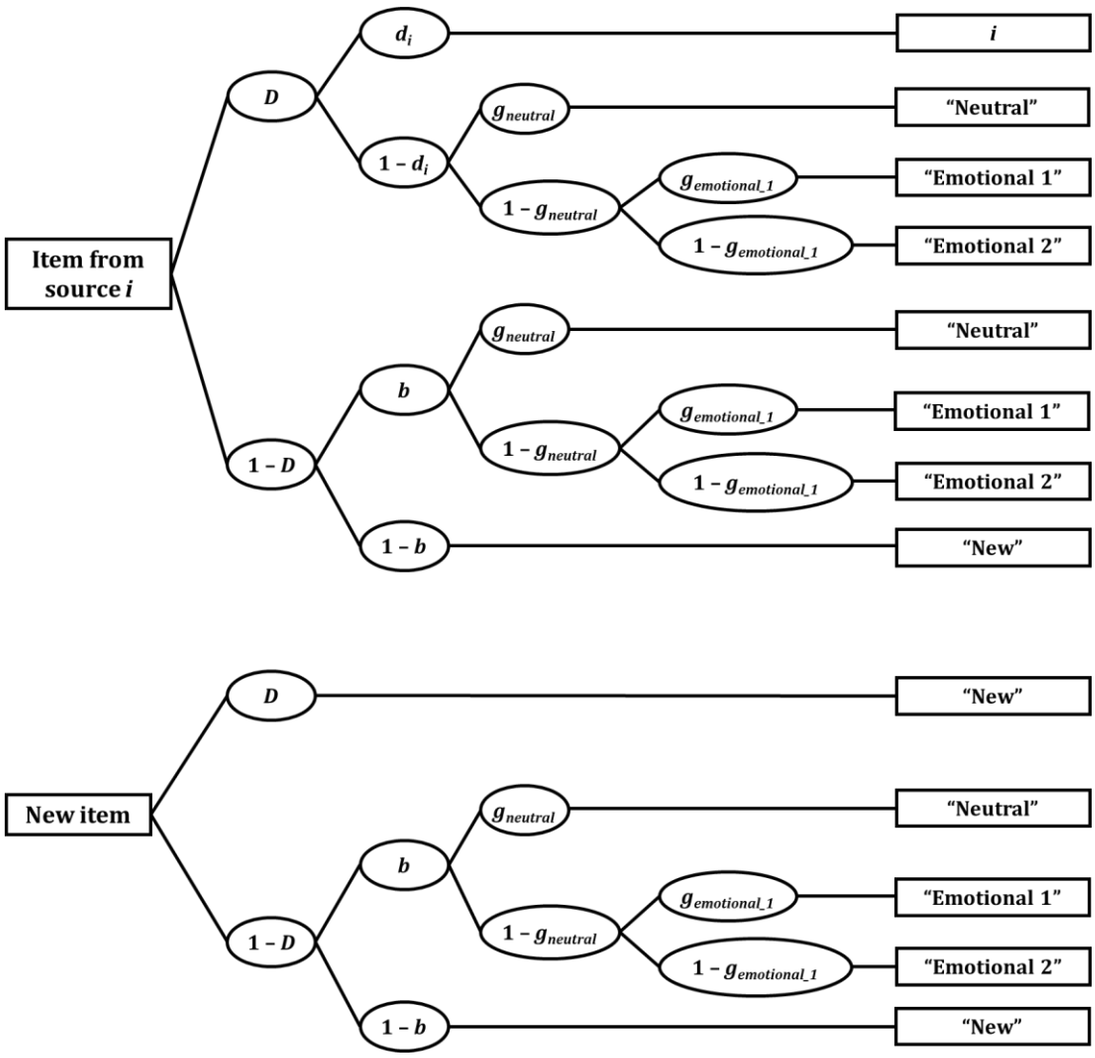


**Figure 2.** Graphical representation of the *two-high-threshold multinomial model of source monitoring* (2HTSM; Bayen et al., 1996) for three sources, adapted from Keefe et al. (2002). *i* denotes the emotionality of the source with which the item was originally paired. *D* = probability of detecting an item as previously presented or not presented; $d_i$ = probability of correctly recalling the source of a recognized item; *b* = probability of guessing that an item was previously presented; $g_{neutral}$ = probability of guessing the neutral source for a detected or undetected item; $g_{emotional\_1}$ = probability of guessing the first (versus second) emotional source for a detected or undetected item when the neutral source was not guessed. Dependent on the research question, emotional sources varied within participants either in their arousal (Manuscript 1) or their valence (Manuscript 2 and 3).

# 4 Identifying Influencing Factors of Emotional Source Memory

In three manuscripts, we investigated whether and when source memory is enhanced for emotional sources by focusing on the following factors: Valence and arousal of sources (Manuscript 1), aging (Manuscript 2), and encoding instructions (Manuscript 3). All conducted experiments rely on the above-described methodological approach. In the following, I will briefly outline each manuscript's substantive focus, its methodological specifics, and its main results.

## 4.1 Manuscript 1: Source Valence Versus Source Arousal

In the first manuscript, we investigated whether source memory is generally enhanced for perceptually (and thus inherently) emotional sources compared to neutral sources and specifically looked at the contribution of valence and arousal to this effect. As reviewed above, research is inconclusive on whether EEM effects occur in source memory, as some studies find such effects (e.g., Bell & Buchner, 2012; Ventura-Bort, Löw, Wendt, Moltó et al., 2016) and others do not (e.g., Arnold et al., 2021; Bell et al., 2017). Notably, the literature on EEM effects in *item memory* emphasizes the importance to separate valence- from arousal-based EEM effects as they seem to rely on different mechanisms (Dolcos et al., 2017; Kensinger & Corkin, 2004). In general, this research suggests that both valence and arousal contribute to EEM effects independently from each other. That is, positive and especially negative items are remembered better compared to neutral items if matched on arousal; and high-arousing items are remembered better than low-arousing items if matched on valence (Kang et al., 2014). Importantly, however, findings additionally suggest that the arousal-based EEM effect might be more robust because it relies on automatic, resource-independent attentional processes (mediated via an amygdala—hippocampus network; Kang et al., 2014; Kensinger & Corkin, 2004; Kern et al., 2005). In contrast, the valence-based EEM effect rather draws on controlled, resource-dependent processes (mediated via a prefrontal-cortex—hippocampus network). As such, it seemed promising to consider and systematically manipulate the valence and arousal of sources as potential factors that contribute to the previous inconclusive findings.

We conducted two experiments in Manuscript 1. In both experiments, we manipulated valence between participants and arousal within participants. That is, we implemented two experimental groups: In the negative group, we used negative sources of high versus low

arousal, whereas, in the positive group, we used positive sources of high versus low arousal to manipulate source emotionality. Neutral sources were additionally used in both groups as the baseline. In both experiments, participants were told to learn the items only, without any (explicit) reference to the sources (i.e., incidental source learning). After a three-minute retention interval, participants were presented with all studied items plus some new items and were asked to make a source-monitoring judgment. The two experiments mainly differed in their item and source material: In Experiment 1, participants learned neutral objects as items, which were presented with a high-arousing, low-arousing, or neutral sound as the source. Sounds were selected based on a pre-study conducted with a German student sample. In Experiment 2, participants learned neutral words as items, which were superimposed on emotional or neutral scenery pictures as sources. Crucially, two picture stimuli were used for each valence-arousal combination in this experiment. That is, one source type (e.g., negative high-arousing source) consisted of two pictures. Further crucially, in Experiment 2, we asked participants to rate the valence and arousal of all source pictures at the end of the study. For a more effective source emotionality manipulation, we included only those participants in our main analysis who perceived the source pictures as intended in terms of valence and arousal.

Results were somewhat surprising: Across both experiments, we did not find any beneficial effects of source valence or source arousal on source memory. That is, source memory was not better for high-arousing (versus low-arousing) sources, and also not better for negative or positive (versus neutral) sources. Interestingly, source memory was reduced for negative high- (versus low-) arousing sources in Experiment 1. This might support research showing that high negative arousal has detrimental effects on hippocampus-dependent memory binding and associative memory (Bisby & Burgess, 2017), considering that source memory is a special case of associative memory (Old & Naveh-Benjamin, 2008). However, this detrimental effect of high negative arousal in Experiment 1 did not hold against Bonferroni-Holm adjustment and did not occur in Experiment 2, even when we inspected a subgroup of people with a particularly high rating difference between the high-arousing and low-arousing negative pictures. This rather suggests that the detrimental arousal effect in Experiment 1 was a false positive.

In total, these first two experiments provide conclusive evidence that source memory is not per se enhanced for emotional compared to neutral sources. This suggests that the EEM effects in source memory observed in other studies rely on (methodological) specifics or factors other than valence and arousal. We thus focused on other factors in the next two manuscripts.

## 4.2 Manuscript 2: Aging

The goal of the second manuscript of this thesis was to investigate whether source emotionality effects differ between older and younger adults. Although the experiments of manuscript 1 suggested no effects of source emotionality on source memory with a young sample, such effects might more readily manifest in older adults (see May et al., 2005; Rahhal et al., 2002). Notably, in this second manuscript, we systematically varied the valence of sources within participants and kept arousal constant at a low-to-medium level. We focused on valence because the literature on emotionality effects in item memory has shown valence-dependent differences between older and younger adults. That is, while younger adults tend to show a negativity bias in item memory (i.e., better memory for negative than for positive items; e.g., Grühn et al., 2007; Spaniol et al., 2008; see Baumeister et al., 2001, for a review), older adults show a positivity bias (i.e., better memory for positive than for negative items) or a reduced negativity bias relative to younger adults (i.e., memory enhancement for negative compared to positive items is weaker in older versus younger adults; e.g., Charles et al., 2003; Kwon et al., 2009). This phenomenon is called the age-related *positivity effect* and has been robustly shown in attention and item memory (see Reed et al., 2014 for a meta-analysis). This effect is theoretically underpinned by the influential *socio-emotional selectivity theory* (SST) of Carstensen (Carstensen et al., 1999), which suggests that, as we age, our motivational priorities shift from future-oriented goals (e.g., knowledge acquisition) to present-oriented goals (e.g., emotional satisfaction). From this perspective, it makes sense that older compared to younger adults more strongly prioritize positive over negative information to maximize their goal of emotional satisfaction. As these effects rely on motivational (goal-related) processes, it is important to keep arousal at a low level because, as discussed above, high-arousing material captures attention automatically and thus counteracts the unfolding of motivational (controlled) processes (see also Kensinger, 2008). Notably, such considerations were lacking in previous studies on source emotionality effects in older versus younger adults, potentially contributing to their inconclusive results.

Across both experiments, the chosen material was similar to Experiment 2 of Manuscript 1 (i.e., neutral words as items superimposed on either emotional or neutral scenery pictures as sources). However, an important difference was that we implemented incidental learning not only for the sources (as in Manuscript 1) but also for the items. This was motivated by Reed et al.'s (2014) meta-analysis, which showed that incidental instructions boost the age-related positivity effect, presumably because an incidental, unconstrained way of

processing supports older and younger adults' inherent processing preferences. More specifically, in both experiments, we implemented an affective, item-focused orienting task during item-source encoding: We asked participants to rate the pleasantness of the neutral item, which was presented with either an emotional (positive or negative) or neutral source. A surprise source-monitoring test was administered after a three-minute retention interval. In Experiment 1, we applied the standard many-to-few mapping of items to sources: Neutral items were presented with either the positive, the negative, or the neutral source picture, resulting in a repeated presentation of the three chosen source pictures. To eliminate habituation effects, which might have occurred due to this repeated source presentation, we applied a one-to-one mapping of items to sources in Experiment 2. That is, each item was presented with a unique source picture (of either positive, negative, or neutral valence) during item-source-encoding, meaning that each picture was presented only once.

Results were highly consistent across both experiments: Younger and older participants incorporated source valence into their pleasantness ratings of the neutral items. That is, items paired with positive sources were rated more pleasant than items paired with neutral sources, which in turn were rated more pleasant than items paired with negative sources (i.e., positive > neutral > negative). Of note, an age-related positivity effect additionally occurred in these pleasantness ratings (see Figure 3): In Experiment 1, older adults rated items paired with the negative source as less unpleasant compared to younger adults (i.e., reduced negativity bias); in Experiment 2, older adults rated items more pleasant than younger adults for all three source types. Importantly, this age-related positivity effect in the pleasantness ratings did not transfer to source memory: While younger adults showed better source memory for emotional (and especially positive) compared to neutral sources, indicating an EEM effect in source memory, older adults' source memory did not differ across source types (Figure 4). This suggests that older adults' source memory did not benefit from emotional sources, as younger adults' source memory did, supporting the findings of Davidson et al. (2006), however contradicting those of May et al. (2005) and Rahhal et al. (2002).

Further notably, despite the common methodological ground across the first and second manuscript, their results were somewhat inconsistent: While no valence-based EEM effects in source memory occurred in Manuscript 1, such effects occurred in Manuscript 2 (for younger adults). However, one important methodological difference was that we used different encoding instructions across manuscripts (i.e., participants were told to learn the items in Manuscript 1 versus to rate the pleasantness of the items in Manuscript 2). To further clar-

ify whether these inconsistent results can be explained by the variation in encoding instructions, we focused on the role of encoding instructions in source emotionality effects in the third manuscript.

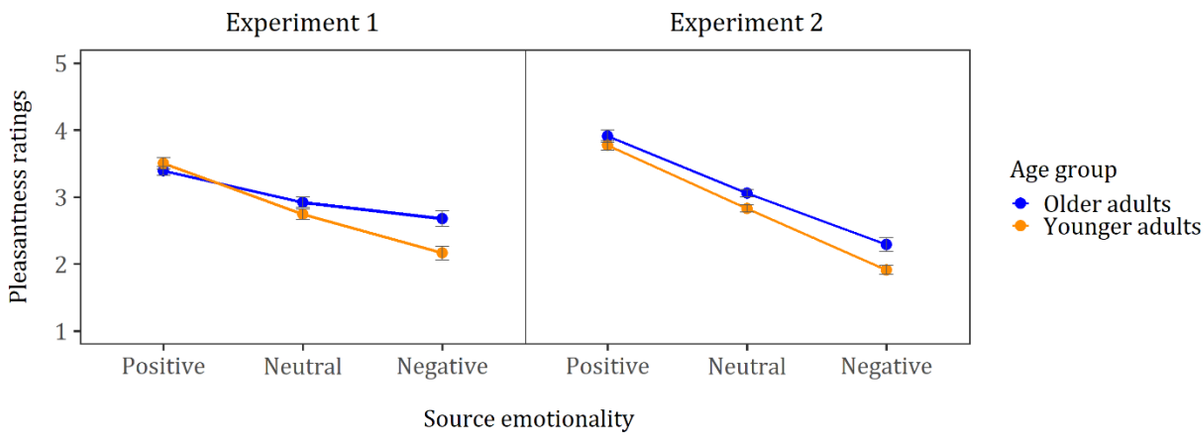


**Figure 3**. Older and younger adults' pleasantness ratings for neutral words during encoding in Experiment 1 (left-hand plot) and Experiment 2 (right-hand plot) of Manuscript 2. Neutral words were presented with either the positive, neutral or negative source. Error bars indicate one standard error of the mean. The pleasantness rating scale ranged from 1 = very unpleasant to 5 = very pleasant.

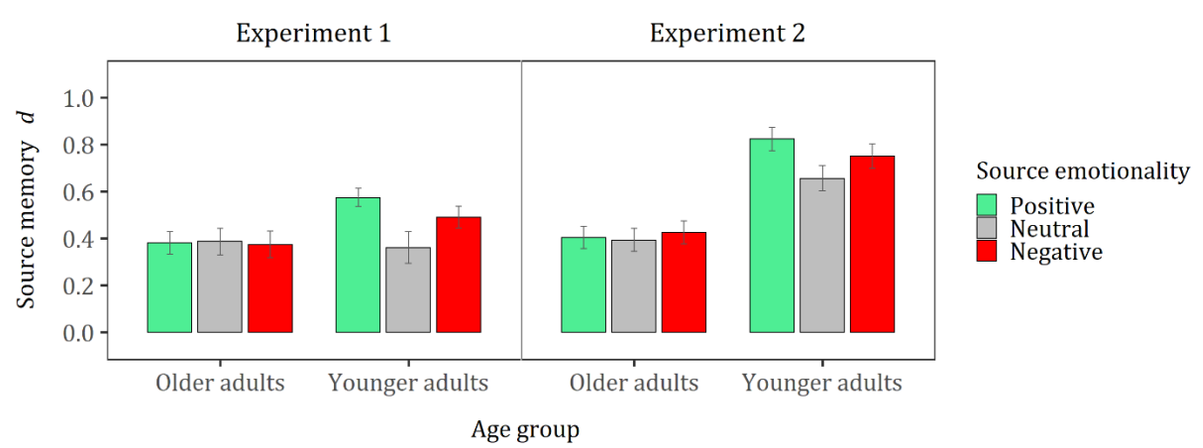


**Figure 4.** Older and younger adults' source memory for the positive, negative, and neutral sources in Experiment 1 (left-hand plot) and Experiment 2 (right-hand plot) of Manuscript 2. Error bars indicate one standard error of the estimate. Note that $d$ = 0 denotes chance performance while $d$ = 1 means perfect source memory.

## 4.3 Manuscript 3: Encoding Instructions

The goal of the third manuscript was to investigate whether the type of encoding instructions influences EEM effects in (younger adults') source memory. With this, we not only aimed at clarifying our own inconclusive results (see previous two manuscripts) but also at clarifying the generally inconsistent findings on source emotionality effects reported in the literature (see *Introduction* section). Interestingly, many studies that reported rather robust EEM effects in source memory applied an affective, item-focused orienting task during item-source encoding (e.g., likeability ratings, see Bell & Buchner, 2012). Combined with the EEM effect found in Manuscript 2, in which we similarly used an affective, item-focused orienting task (i.e., pleasantness ratings), it seems that such instructions might foster EEM effects in source memory. We initially deemed that integrative item-source processing might drive these effects. More specifically, we hypothesized that affective judgments during encoding potentially boost integrative item-source processing because participants can use the sources to inform their judgment about the neutral item. An integrative item-source processing, in turn, benefits source memory, leading to the observed EEM effects. Notably, this idea is further in line with research showing that an EEM effect in source memory can also be established with integrative (non-affective) encoding instructions (Smith et al., 2004; Ventura-Bort, Löw, Wendt, Moltó et al., 2016). Before testing our proposition, we first wanted to replicate the source emotionality effect found in Manuscript 2. Thus, in Experiment 1 of Manuscript 3, we used emotional versus neutral pictures as sources (one per source type), neutral words as items, and an affective orienting task (i.e., pleasantness ratings) for an incidental item-source encoding (cf., Manuscript 2 for more details). We found better source memory for emotional compared to neutral sources, thus replicating the results of Manuscript 2 (for younger adults). In Experiment 2, we aimed at systematically testing under which encoding conditions EEM effects in source memory occur. More specifically, we used the same type of material as in Experiment 1 (neutral words as items superimposed on emotional or neutral pictures as sources), but encoding instructions differed across the four implemented conditions: In the affective orienting task (OT) condition, participants judged the pleasantness of the neutral items (cf., Experiment 1); in the integrative OT condition, participants judged how well the item fits to the source; in the non-integrative OT condition, participants indicated whether the item represents something living or something non-living; and finally, in the no-OT condition, participants (intentionally) learned the items without any (explicit) reference to the sources. Note that in the no-OT condition, we applied the same encoding instructions (intentional item and incidental source learning) as in Manuscript 1. Further note that across

all four conditions, sources were encoded incidentally. Memory was tested in a standard source-monitoring test briefly after encoding. We expected to replicate the source emotionality effect on source memory found in Experiment 1 (and Manuscript 2) in the affective OT condition. Notably, based on the above reasoning, EEM effects should occur whenever an integrative item-source encoding is fostered. Thus, we also expected to find an EEM effect in the integrative OT condition, which explicitly encouraged integrative processing. No EEM effects in source memory were expected in the non-integrative and no-OT conditions, as these conditions fostered a rather segregated item-source encoding. Replicating our previous results, we found better source memory for the emotional (and especially positive) sources compared to the neutral source in the affective OT condition (see Figure 5). Surprisingly, no EEM effects in source memory could be established in the integrative OT condition. Finally, no EEM effects occurred in the non-integrative condition and the no-OT condition, as expected (see Figure 5). However, in the no-OT condition, source memory was higher for the positive compared to the negative source (significantly) and neutral source (descriptively). This was presumably because participants found it easier to relate the items to the positive (compared to the negative and neutral) source, as their item-source-fit judgments from the integrative OT condition indicated (see *General Discussion*).

Taken together, across two experiments, we robustly found an EEM effect in source memory when using an affective orienting task during item-source encoding. However, no such effect occurred in the integrative OT condition, which explicitly encouraged integrative processing. This contradicts our idea that EEM effects in source memory occur whenever an integrative item-source encoding is fostered. Instead, it seems that there is something special about the affective orienting task. Possibly, the affective orienting task made sources' valence more salient and meaningful during encoding, thus resulting in the observed EEM effect (see *General Discussion* for a more detailed discussion). In sum, Manuscript 3 clearly shows that EEM effects in source memory are fostered by an affective item-source encoding. With this, our research contributes to a better understanding of the conditions that foster versus hinder source emotionality effects.

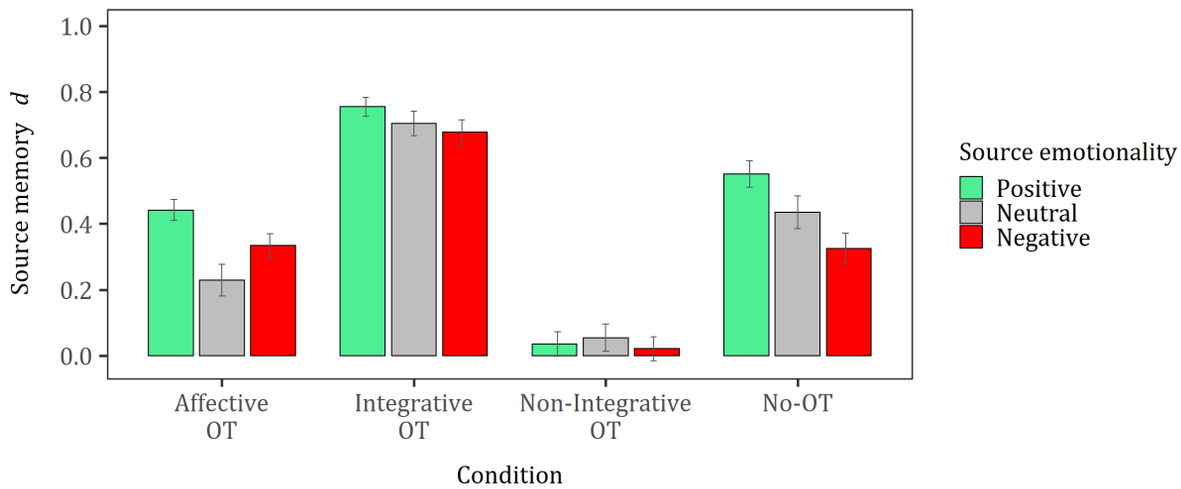


**Figure 5.** Source memory for the positive, negative, and neutral sources in the affective orienting task (OT), integrative OT, non-integrative OT, and no-OT condition of Experiment 2 of Manuscript 3. Error bars indicate one standard error of estimate. Note that $d = 0$ denotes chance performance while $d = 1$ means perfect source memory.

# 5 General Discussion

This dissertation aimed to systematically investigate whether and under which conditions source memory is enhanced for emotional compared to neutral sources. By shifting the research focus from emotional items to emotional sources, this thesis significantly extends the literature on emotion-enhanced memory (EEM) and thus contributes to a broader view on how emotion influences episodic memory. The developed research program carefully considered previous, inconclusive findings on EEM effects in source memory and, based on this, identified three important factors that might have contributed to such result inconsistencies: valence and arousal of sources, aging, and encoding instructions. Using a joint experimental approach, these factors were systematically investigated in three manuscripts.

In the first manuscript, we investigated whether source memory was enhanced for external, perceptually emotional sources and whether valence versus arousal of sources would independently contribute to this (potential) memory benefit. To ensure a natural, unforced source processing, we applied incidental instructions for source learning but intentional instructions for item learning. Somewhat surprisingly, no beneficial effects of source valence or source arousal on source memory could be established across the two experiments. These findings suggest that emotional sources are not "by default" remembered better and that additional factors might be necessary to promote EEM effects.

In the second manuscript, we investigated whether EEM effects in source memory differ between younger and older adults (see May et al., 2005). We further tested whether older adults specifically benefit from positive compared to negative sources, akin to the seemingly robust age-related positivity effect found in item memory (Reed et al., 2014). We used an affective, item-focused orienting task (i.e., item-pleasantness ratings) to ensure incidental item and source learning. Contrary to our expectations, older adults' source memory did not benefit from emotional (or specifically positive) sources. In contrast, younger adults showed better source memory for emotional compared to neutral sources, indicating a valence-based EEM effect in source memory. Combining the results of Manuscripts 1 and 2, it seemed that the presence versus absence of EEM effects in source memory partially depended on the type of instructions used during item-source encoding. This idea was investigated in the third manuscript.

In Manuscript 3, we first successfully replicated the EEM effect in younger adults' source memory observed in the second manuscript, thus verifying the robustness of this effect. In a second experiment, we systematically varied the type of item-source encoding by either applying an affective orienting task (OT; as in Manuscript 2), an integrative but non-

affective OT (new), a non-integrative OT (new), or intentional item encoding instructions (no-OT condition; as in Manuscript 1). Source memory was enhanced for emotional compared to neutral sources in the affective orienting task condition only, emphasizing the importance of affective encoding instructions for source emotionality effects. Interestingly, in the no-OT condition, source memory was higher for the positive compared to the negative source, which was presumably driven by the higher relatedness of the neutral items to the positive source. Manuscript 3 illustrates that spontaneous EEM effects in source memory seem to occur only when source emotionality is salient and meaningful during item-source processing.

Altogether, this thesis contributes to clarifying previous inconsistent results on EEM effects in source memory by specifying conditions under which such EEM effects are present versus absent. On a broader level, the thesis shows that source emotionality per se does not benefit source memory. This implies that the robust EEM effect found for item memory does not simply transfer to source memory, thus underpinning the theoretical distinction of (recollection-based) source memory from (familiarity-supported) item memory (Kuhlmann et al., 2021; Mitchell & Johnson, 2009).

## 5.1 Strengths and Limitations

This dissertation stands out from previous research particularly due to its methodological soundness. In all studies, the standard source-monitoring paradigm and the two-high-threshold multinomial model of source monitoring (2HTSM) were applied, thus following a well-established approach to investigate and measure source memory (Bayen et al., 1996). Also, to achieve good statistical power, the sample size was always determined via a priori power analyses. Estimates for the effect of interest (i.e., the difference in source memory parameters *d* of the 2HTSM) were carefully derived based on the current state of evidence. Further crucially, perceptually emotional stimuli were used as sources to ensure an effective emotionality manipulation. Additionally, great efforts were undertaken when selecting the source material: Valence and arousal were systematically considered by either varying both independent of each other (Manuscript 1) or by varying valence and keeping arousal constant (Manuscripts 2 and 3). Crucially, the emotionality of the selected source material was additionally checked by collecting valence and arousal ratings either post-hoc (after the experiment) or a priory (in a pre-study). To the best of my knowledge, no previous work has done this in such a careful and thorough manner. Another shortcoming of previous studies was that they used material or instructions which facilitated the processing of items and sources as one joint unit (e.g., Bell & Buchner, 2010; Ventura-Bort, Löw, Wendt, Moltó et al., 2016).

This considerably blurs the distinction between source and item memory. To avoid such a confound, the sources used in this dissertation were external and unrelated to the items. In addition, source learning was always incidental, and instructions never put focus on the item-source relation (with the exception of the integrative OT condition in Manuscript 3, which was deliberate and aimed at investigating the impact of such relational item-source encoding). At large, the experimental approach used in this dissertation was specifically tailored to the investigation of emotional source memory and future studies could continue to use this approach to add to this research line.

Having said that, it is also important to acknowledge the limitations of this dissertation. One limitation was that only a small number of stimuli were used for the source emotionality manipulation. More specifically, following the standard approach of many-to-few mapping of items to sources (i.e., one source presents many items; Glisky et al., 1995), each source type (e.g., negative source) typically consisted of one stimulus (e.g., one negative picture). As this implied a repeated presentation of sources across study trials, participants might have habituated to the emotional material. Another problem with using only one stimulus per source is the resulting confound between emotionality and the specific content of the respective stimulus. For example, in Experiment 1 of Manuscript 2, it is unclear whether the enhanced source memory for the positive source picture was due to its positive valence or due to its specific content (i.e., depicted lake). However, these problems were considered and addressed within each manuscript. That is, in Manuscript 1, we used two pictures for each source type in Experiment 2 to reduce habituation and counteract stimulus-specific, idiosyncratic effects. Similarly, in Manuscript 2, we opted for a one-to-one mapping of items to sources in Experiment 2, presenting each item with a different, unique source picture, thus eliminating the risk of habituation and stimulus-specific effects. In Manuscript 3, we observed EEM effects in source memory only when using an affective orienting task during encoding. As habituation (or stimulus-specific) effects should have been similarly pronounced in all conditions, they cannot sufficiently account for the observed condition-sensitive result patterns. To conclude, although habituation effects and stimulus-specific effects are generally valid concerns, such effects do not constrain the findings and conclusions of this dissertation. Future research on emotional source memory could consider to consistently use a one-to-one mapping of items to sources (i.e., pairing each item with a unique source), as the standard many-to-few mapping approach comes with the risk of habituation effects. Note, however, that having unique sources complicates the differentiation between what is the source and what is the item, as a typical feature of sources is their recurring nature (Kuhlmann et al.,

2021). Thus, a one-to-one mapping might rather tap into item-to-item binding instead of item-to-source binding, and emotionality effects potentially differ between these two binding types (see next section). Another way to reduce habituation effects but keep a many-to-few mapping procedure is to use emotional source themes (e.g., pollution as the negative theme), which contain several (e.g., two or three) stimuli per theme, as was done in Manuscript 1, Experiment 2. In this case, the source theme is recurring and thus not unique (tapping into item-source binding), but at the same time consists of several instead of only one stimulus (reducing habituation effects).

## 5.2 Future Directions

While fostering the understanding of EEM effects in source memory, the findings of this dissertation also prompt new questions and highlight potential future directions. In the following, I will discuss some of these current research gaps, first with regard to source arousal, and then with regard to source valence.

### 5.2.1 Source Arousal

Although effects of source arousal were investigated in both studies of Manuscript 1, these studies did not use an affective orienting task during item-source-encoding but rather instructed participants to memorize the items only. For source valence, we now know that such affective encoding instructions can foster EEM effects in source memory (see Manuscript 3). Future studies could investigate whether high-arousing sources similarly affect source memory if an affective orienting task is used during encoding. It is noteworthy, however, that the investigation of arousal effects comes with two major challenges. From a theoretical perceptive, the empirical evidence on how arousal affects associative memory binding, including item-to-source binding (i.e., source memory), has been highly inconclusive (see Bisby et al., 2016; Cook et al., 2007; Pierce & Kensinger, 2011, for detrimental effects; Doerksen & Shimamura, 2001; Guillet & Arndt, 2009; Nadarevic, 2017, for beneficial effects; and Meyer et al., 2015; Naveh-Benjamin et al., 2012, for null-effects), prompting an ongoing debate and comprehensive accounts on this issue (e.g., Bisby & Burgess, 2017; Chiu et al., 2013; Levine & Edelstein, 2009; Mather, 2007; Mather & Sutherland, 2011). These accounts mostly rely on studies that have used high-arousing items (not sources) to investigate the impact of arousal on associative binding, but some accounts also enable predictions for the effects of high-arousing sources. One such account is the dual-representation theory by Bisby and col-

leagues (Bisby et al., 2016; Bisby & Burgess, 2017). It suggests that (negative) arousal benefits amygdala-dependent memory representations, such as memory for emotional items, but disrupts hippocampally-dependent memory representations, such as memory for associations. As memory for item-source associations (i.e., source memory) has been shown to rely on hippocampal activity (Mitchell & Johnson, 2009), this account would predict reduced (instead of enhanced) source memory for (negative) high-arousing compared to low-arousing sources. Although the studies of Manuscript 1 did not support this prediction, more research is needed to identify potential boundary conditions for the occurrence of such disruptive effects. For example, Bisby et al. typically present two pictures (each being either emotional or neutral) and use associative imagery instructions during encoding, (e.g., asking participants to create a mental image that includes all to-be-bound elements; Bisby et al., 2018). Such instructions foster the binding of separate elements into a coherent memory representation. Put differently, disruptive effects of arousal on the hippocampus and thus on associative memory might become apparent only when binding processes are explicitly encouraged via instructions, which was not the case in Manuscript 1, as instructions focused only on the item, not on item-source binding.

Note, however, that such imagery instructions have also been successfully used to facilitate item-source-unitization (Diana et al., 2008; Murray & Kensinger, 2012), fostering the representation of separate elements as one bound unit in memory (instead of distinct, related elements). Such bound units, in turn, have been shown to rely *less* on the hippocampus (Diana et al., 2007; Murray & Kensinger, 2013) and thus should be less affected by hippocampal disruptions caused by (negative) arousal. Considering this, the question arises why imagery instructions sometimes seem to foster hippocampus-dependent associative binding (as in Bisby & Burgess, 2017) and sometimes lead to hippocampus-independent unitization (as in Diana et al., 2008). This might partially depend on the type of binding. Unitization might be easier to induce for item-to-source (compared to item-to-item) associations because items and sources are often perceptually or semantically linked in source-monitoring experiments (e.g., font color [source] of words [items], Doerksen & Schimamura, 2001; location [source] signals safety of food [item], May et al., 2005). Future experiments could test whether unitization difficulty and success systematically vary across item-source versus item-item associations by applying both behavioral (Murray & Kensinger, 2012) and neurological measures (Diana et al., 2007) of unitization. In sum, future research on arousal and binding needs to

take into account that arousal effects might depend on the type of binding (item-source versus item-item), the type of encoding instructions (e.g., incidental versus mental imagery), or an interaction between both.

Further notably, Bisby et al. (2016) do not specify whether hippocampal disruptions rely on high arousal, negative valence, or a combination of both (see also Bisby & Burgess, 2013). They use these terms interchangeably and typically contrast (associative) memory for negative high-arousing stimuli against neutral low-arousing stimuli in their studies, thus confounding the effects of high arousal and negative valence. This leads us to the second, methodological challenge associated with investigating the effects of arousal on (associative) memory. In many established normative databases of perceptually emotional stimuli (e.g., International Affective Picture System [IAPS], Lang et al., 2008; IADS, Bradley & Lang, 2007; Geneva affective picture database [GAPED], Dan-Glauser & Scherer, 2011), the relation between valence and arousal ratings typically follows an asymmetrical *V*-shape (see also Kurdi et al., 2017). Put simply, there are no (or very few) negative and positive stimuli with low arousal levels and no (or very few) neutral stimuli with high arousal levels. This makes it difficult to investigate arousal effects independent of valence. Although Russell (1980) assumed independence of arousal and valence in his pioneering work of the circumplex model, there are different views on what the relation between valence and arousal might look like. In a comprehensive analysis, Kuppens et al. (2013) confirmed that the empirical relation seems to follow an asymmetrical *V*-shape. However, as there are large individual differences in the shape of this relation, the authors conclude that the *V*-shaped relation is weak and that "(…) affective experiences of all combinations of valence and arousal can occur (e.g., low arousal but highly positive or negative affect states do occur, although less frequently)" (p. 933). Building on this, Kurdi et al. (2017) have stressed the need to add negative and positive low-arousing stimuli to emotional databases. Of note, such databases would also profit from adding age norms as valence and arousal perception might vary between younger and older adults (Grühn & Scheibe, 2008; Kurdi et al., 2017).

### 5.2.2 Source Valence

Manuscripts 2 and 3 substantially contribute to clarifying the effects of source valence on source memory: Beneficial effects can be robustly established when an affective, item-focused orienting task (i.e., item-pleasantness ratings) is used during item-source-encoding, suggesting that the valence effect is tied to the affective encoding instructions. However, the exact mechanisms remain rather unclear. After careful consideration of the full result pattern,

we deem that the affective encoding instructions stand out from the other instructions used in our experiments in two main ways. First, the pleasantness judgments made the valence of the source more salient because pleasantness directly maps onto valence. Second, as the affective task focused on the items only, it did not constrain participants to process the sources in a certain way. Put differently, participants were free to pursue their goals and preferences when processing the sources. They were thus inclined to process the emotional (over the neutral) sources because emotional stimuli are, in general, more salient and goal-relevant than neutral stimuli (Levine & Edelstein, 2009; Mather & Sutherland, 2011). This ultimately resulted in the observed EEM effect. Put simply, the general dominance of emotional over neutral sources more clearly comes through if the experimental instructions increase the salience of the source's emotionality but at the same time put minimal constraints on participants' source processing. This can also explain why EEM effects were absent in the integrative OT condition. Here, participants were strongly constrained to engage in an integrative item-source-processing, thus increasing source memory for all three sources, not only for the emotional ones. However, more research is needed to investigate whether salience of source emotionality and experimental constraints on source processing indeed determine the unfolding of EEM effects.

Relatedly, future studies could examine whether EEM effects in source memory occur if sources are learned intentionally (rather than incidentally). Although intentional encoding instructions prompt participants towards an integrative item-source-processing (cf., integrative OT condition), the occurrence of EEM effects might strongly depend on the strategies participants use (or are instructed to use) during item-source-encoding. For example, EEM effects might more readily manifest if participants use a mediator to connect items to emotional versus neutral sources (e.g., a mental image that contains both item and source; see Ventura-Bort, Löw, Wendt, Moltó et al., 2016). This could be investigated more systematically in future studies by manipulating participants' strategy use (e.g., mediator-based versus spontaneous; cf., Kuhlmann & Touron, 2012, during encoding).

Notably, such strategies could also help in establishing an EEM effect in older adults' source memory. To reiterate, in Manuscript 2, EEM effects in source memory manifested only in younger but not in older adults. This was surprising because source valence affected older adults' word-pleasantness ratings in the expected way (i.e., age-related positivity effect), indicating that they not only considered the sources while processing the items, but they did it in a way that matched their processing preferences. However, this was apparently insufficient to boost their source memory. As noted, we think that older adults potentially need an

additional, explicit mediator during encoding (e.g., a sentence or image; see Kuhlmann & Touron, 2012) that links the item to the source. In fact, May et al. (2005) as well as Rahhal et al. (2002), who established EEM effects in older adults' source memory, provide such a mediator by linking item and source via an emotional concept (i.e., source signals threat/safety of the item in May et al.; and truth/falsehood in Rahhal et al.). Thus, strictly speaking, May et al. manipulated the emotionality of the item-source-*link*, not the emotionality of the source itself. Future studies could investigate whether older adults' source memory would benefit from perceptually emotional sources if participants are additionally provided with a mediator for the item-to-source link. Note, however, that such mediators (as used in May et al. and Rahhal et al.) might foster the storage of the item-source pair as one unit (i.e., item-source-unitization), which then blurs the distinction between item and source memory and their underlying processes (Diana et al., 2008). Thus, any observed emotionality effect or positivity effect could then rely on (familiarity-supported) item memory processes (i.e., remembering the emotional item-source-unit) instead of (recollection-based) source memory processes (i.e., remembering the emotional source).

More generally, the literature on age-related emotionality effects in memory, and the positivity effect, in particular, would profit from a more thorough investigation of the conditions that favor or moderate such effects. The meta-analysis of Reed et al. (2014) identified two important moderators of the age-related positivity effect in attention and item memory: the experimental constraints imposed on encoding (the fewer, the stronger the effect) and the age difference between the younger and older sample (the larger, the stronger the effect). However, the studies included in this meta-analysis considerably vary across several other (methodological) factors that might similarly moderate the age-related positivity effect. For example, it is unclear whether the effect differs in size across different types of stimuli (e.g., social stimuli such as faces versus non-social stimuli such as pictures) or different types of memory tests (e.g., recognition versus free recall). Our own review of the literature indicated that the latter factor (i.e., type of memory test) might be a promising moderator. More specifically, the positivity effect seems to manifest more robustly in studies applying a free recall test instead of a recognition test (e.g., Charles et al., 2003; Tomaszczyk et al., 2008). As free recall is more retrieval-demanding than recognition (Riefer & Rouder, 1992; Rouder & Batchelder, 1998), this might suggest that the age-related positivity effect relies on a retrieval rather than a storage advantage. Note, however, that free recall and recognition also put different demands on recollection-based processes, with free recall being fully dependent on recollection while recognition also relies on familiarity (Yonelinas et al., 2001). Yet, the idea

of a primarily recollection-based positivity effect is rather disproved by Manuscript 2, as we do not find such an effect in (recollection-dependent) source memory (see also Kapucu et al., 2008). However, any conclusion about the underlying processes of the positivity effect would be premature at this point. Future research should first establish whether the effect is indeed moderated by the type of memory test before investigating underlying processes.

Another result pattern that merits further attention in future research is that in both studies of Manuscript 2 and Manuscript 3, source memory for positive sources was slightly but persistently higher than for negative (and neutral) sources. Interestingly, participants in Experiment 2 of Manuscript 3 rated the item-source fit (integrative condition) higher for the positive compared to the negative and neutral source. This indicates a higher relatedness between the neutral word items and the positive source picture, which potentially facilitated their binding and resulted in the observed higher source memory for the positive source. Of note, this pattern descriptively showed up across four experiments (Manuscript 2 and Manuscript 3). This suggests that the effect is tied to positive valence in general rather than the specific positive picture because different pictures constituted the positive source across experiments. In fact, Ventura-Bort, Löw, Wendt, Dolcos et al. (2016) similarly found that participants reported higher success in imagining neutral objects as part of positive (versus negative or neutral) sceneries, again pointing to a higher relatedness. Future studies could investigate why there is a higher relatedness between neutral and positive stimuli and more systematically test how it affects source memory and associative memory.

Finally, it is worthwhile mentioning that all our studies investigated whether source memory is enhanced for the general emotional tone of a source (e.g., was the source positive, negative, or neutral?). Thus, it remains unclear how *specific* source memory is for emotional sources. That is, future studies could investigate whether people are better at discriminating between three positive (or negative) sources than three neutral sources. A study by Bell, Buchner, Erdfelder et al. (2012) suggests that source memory is only better for the general, emotional category of the source (i.e., cheating versus trustworthy behavior) but not for specific source details (i.e., specific behavior). However, it still remains unclear whether participants would be better at differentiating between negative (or positive) source categories than between neutral source categories. Future studies could, for example, investigate this by applying three negative sources in one condition versus three neutral sources in the other condition and compare participants' source memory across these conditions. If emotion indeed boosts recollection, then participants' source memory should be better when sources are negative rather than neutral. Of note, encoding instructions might again play a crucial role

here, as they significantly shape how and to what extent participants engage in relational item-source processing.

## 5.3 Conclusion

The goal of this thesis was to investigate whether and under which conditions emotional sources are remembered better. Overall, the findings of this research clearly show that the mere presence of emotional sources does *not* enhance source memory. Focusing on three influencing factors (source valence and source arousal, aging, and encoding instructions), I identified important boundary conditions that foster versus hinder EEM effects in source memory. With this, my dissertation significantly contributes to clarifying previous inconsistent results and provides a fruitful basis for future research. When all is said and done, it seems that emotion does not always benefit memory.

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*You can do what you want,*
*but you cannot want what you want.*

– From the series *Dark*,
inspired by Arthur Schopenhauer

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♡

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• David, who many times saved my life with his expertise in R and lab.js. Thank you for comforting me with your kindness and infinite optimism. Our pink-red debate is still on, though.

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Nikoletta Symeonidou

Mannheim, May 2022

♡

# B Statement of Originality

1. I hereby declare that the presented doctoral dissertation with the title *Emotional Source Memory: (When) Are Emotional Sources Remembered Better?* is my own work.
2. I did not seek unauthorized assistance of a third party and I have employed no other sources or means except the ones listed. I clearly marked any quotations derived from the works of others.
3. I did not present this doctoral dissertation or parts of it at any other higher education institution in Germany or abroad.
4. I hereby confirm the accuracy of the declaration above.
5. I am aware of the significance of this declaration and the legal consequences in case of untrue or incomplete statements.

I affirm in lieu of oath that the statements above are, to the best of my knowledge, true and complete.

Signature:

Date:

# C Co-Authors' Statements

## Co-Author: Beatrice G. Kuhlmann

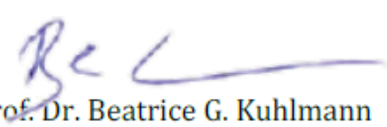
I hereby confirm that the following manuscripts included in the thesis *Emotional Source Memory: (When) Are Emotional Sources Remembered Better?* were primarily conceived and written by Nikoletta Symeonidou, Ph.D. candidate at the University of Mannheim:

Symeonidou, N., & Kuhlmann, B. G. (2022). Better memory for emotional sources? A systematic evaluation of source valence and arousal in source memory. *Cognition and Emotion*, *36*(2), 300-316. https://doi.org/10.1080/02699931.2021.2008323

Symeonidou, N., Hassan, A., Porstein, I. & Kuhlmann, B. G. (2022). Is there an emotionality effect in older adults' source memory? *Aging, Neuropsychology and Cognition*. Advance online publication. https://doi.org/10.1080/13825585.2022.2078778

Symeonidou, N., & Kuhlmann, B. G. (2022). *Enhanced source memory for emotional sources: Does an affective orienting task make the difference?* Manuscript submitted for publication.

I sign this statement to the effect that Nikoletta Symeonidou is credited as the primary source of the ideas and the main author of the three above-listed manuscripts. She derived the research questions for the first and third manuscripts and refined the question in the second manuscript, programmed all experiments, collected the data or monitored the data collection, conducted the data analyses, wrote the first drafts, and was responsible for revising all manuscripts. I derived the research question for the second manuscript, contributed to developing and refining the research questions in the other two manuscripts, performed the statistical analyses for Experiment 1 in the second manuscript, suggested ideas for additional analyses for all three manuscripts, provided recommendations for structuring the manuscripts, and contributed to refining and revising the drafts of all manuscripts.



Prof. Dr. Beatrice G. Kuhlmann

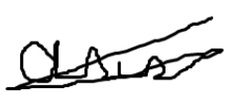
Mannheim, May 2022

## Co-Author: Abdolaziz Hassan

I hereby confirm that the following manuscript included in the thesis *Emotional Source Memory: (When) Are Emotional Sources Remembered Better?* was primarily conceived and written by Nikoletta Symeonidou, Ph.D. candidate at the University of Mannheim:

Symeonidou, N., Hassan, A., Porstein, I. & Kuhlmann, B. G. (2022). Is there an emotionality effect in older adults' source memory? *Aging, Neuropsychology and Cognition*. Advance online publication. https://doi.org/10.1080/13825585.2022.2078778

I sign this statement to the effect that Nikoletta Symeonidou is credited as the primary source of the ideas and the main author of the above-stated manuscript. She programmed the experiments, monitored the data collection for Experiment 2, performed the data analyses, wrote the first draft, and was responsible for revising and improving the manuscript. I contributed to developing the theoretical background, designing and refining Experiment 1 of the manuscript, collecting the data for Experiment 1, and improving the manuscript.



Abdolaziz Hassan

Mannheim, May 2022

## Co-Author: Isabel Porstein

I hereby confirm that the following manuscript included in the thesis *Emotional Source Memory: (When) Are Emotional Sources Remembered Better?* was primarily conceived and written by Nikoletta Symeonidou, Ph.D. candidate at the University of Mannheim:

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I sign this statement to the effect that Nikoletta Symeonidou is credited as the primary source of the ideas and the main author of the above-stated manuscript. She programmed the experiments, monitored the data collection for Experiment 2, conducted the data analyses, wrote the first draft, and was responsible for revising and improving the manuscript. I contributed to refining the theoretical background, designing and refining Experiment 2 of the manuscript, and revising the second draft of the manuscript.

Isabel Porstein

Mannheim, May 2022

# D Copies of Manuscript

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