



## Investigating Self-Representations:

An assessment of the generation of self-representations  
and how they affect cognitive processes

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I could not imagine having a better PhD time!

## Abstract

Due to the vast amount of information which we are experiencing at every moment, reliable, functional mechanisms are indispensable to guide us through the flood of information. Aiming at an efficient and meaningful selection of a sample of information for further processing, attention and cognitive capacities should be focussed on personally relevant content. A therefore necessary appropriate definition of this personally relevant content can be based on a robust self-representation, which has to be specific, on the one hand, and adaptive to changes, on the other hand. Regarding a huge amount of research handling the still unanswered question whether self-relevance can be understood as a general selection mechanism, the dissertation at hand provides a deeper understanding of the generation and adaptation of self-representations. Five articles are presented which use a recently introduced paradigm, the so-called matching paradigm (Sui, He, & Humphreys, 2012) and which yield empirical evidence concerning the influence of self-representations on cognitive processes. In detail, a compound of studies described in the first article checked for (and confirmed) the adequacy of the matching paradigm as a tool to assess effects of self-relevance. In the second article, a study is presented in which the generation of self-representations was assessed, revealing a deeper understanding of cognitive aspects which contribute to self-representations. Following up this first description of self-representations, the third and fourth article point out particular characteristics of the content which can potentially be integrated into the self-representation. Finally, two studies presented in the fifth article compared effects of self-relevance to effects of negative valence (as negative valence is supposed to represent a general selection mechanism), gaining at a specification of the influence of self-relevance on stimulus processing. In sum, it can be concluded from the presented empirical findings that the self can be conceptualized as a specific, complex network of associations between concepts and that self-relevance facilitates stimulus integration rather than guiding attention automatically.

## Zusammenfassung (deutsch)

Aufgrund der enormen Menge an Informationen, die wir in jedem einzelnen Moment erleben, sind zuverlässige und funktionale Mechanismen, die uns durch die Informationsflut leiten, unerlässlich. Um effizient und sinnvoll einzelne Informationen für die weitere Verarbeitung auszuwählen, sollten die Aufmerksamkeit und kognitive Kapazitäten auf persönlich relevante Inhalte fokussieren. Eine dazu nötige, angemessene Definition von persönlicher Relevanz könnte auf einer stabilen Selbstrepräsentation beruhen, die zum einem spezifisch und zum anderen flexibel bei Veränderungen sein sollte. In Anbetracht einer Vielzahl von Forschungsergebnissen in Bezug auf die noch ungeklärte Frage, inwiefern Selbstrelevanz als allgemeiner Selektionsmechanismus begriffen werden kann, liefert die hier vorliegende Dissertation ein genaueres Verständnis von der Entstehung und Anpassung einer Selbstrepräsentation. Es werden fünf Artikel vorgestellt, die ein relativ neues Paradigma, das sogenannte Matching-Paradigma (Sui, He, & Humphreys, 2012) verwenden und die empirische Evidenz dafür liefern, wie Selbstrepräsentationen kognitive Prozesse beeinflussen. Genauer wird in einem ersten Artikel eine Zusammenschau von Experimenten geliefert, die die Tauglichkeit des Matching-Paradigmas zur Messung von Selbstrelevanzeffekten beurteilt (und bestätigt). In einem zweiten Artikel wird eine Studie vorgestellt, in der die Entstehung von Selbstrepräsentationen untersucht wurde, was zu einem genaueren Verständnis der an der Entstehung von Selbstrepräsentation beteiligten kognitiven Prozesse führt. An diese erste Beschreibung von Selbstrepräsentationen anknüpfend, beschreiben der dritte und vierte Artikel konkrete Charakteristika von Inhalten, die in die Selbstrepräsentation integriert werden können. Schließlich werden in dem fünften Artikel zwei Studien erläutert, in denen Effekte von Selbstrelevanz mit Effekten von negativer Valenz (die als genereller Selektionsmechanismus angesehen wird) verglichen werden, was zu einer Spezifikation des Einflusses von Selbstrelevanz auf Reizverarbeitung beiträgt. Insgesamt kann aufgrund der empirischen Befunde, die in der vorliegenden Dissertation erläutert werden, schlussgefolgert werden, dass das Selbst verstanden werden kann als ein spezifisches, komplexes Netzwerk von Assoziationen zwischen Konzepten und dass Selbstrelevanz die Integration von Inhalten begünstigt, nicht aber die Aufmerksamkeit automatisch lenkt.

## 1. Self-relevance in everyday perception

In everyday life, we often search for pieces of information which are in one way or another related to our self: Does anyone like or dislike myself? Is she talking about me? Did they cite my publication? The assumption that people are particularly interested in pieces of information which are relevant for themselves, might on the first sight be interpreted to reflect quite an egocentric behavior, but a huge amount of empirical findings support this assumption. That is, the self-relevance of particular stimuli leads to a robust prioritization of these stimuli, measured on a variety of behavioral measures. For example, the *self-reference effect* describes the phenomenon that information which is actively related to the self while learning (“Does this adjective describe you?”) is more likely to be recalled than information which is elaborated on a non-self-related dimension (for a review, see Symons & Johnson, 1997). The *mere-ownership effect* alike denotes the finding that objects are evaluated more favorably and recognized more precisely when they are arbitrarily assigned to the self (Beggan, 1992; Cunningham, Turk, Macdonald, & Macrae, 2008). Further, stimuli which are associated with the self, like the initial letters of one’s name, were evaluated more positive than neutral letters (Koole, Dijksterhuis, & van Knippenberg, 2001).

Moreover, in different paradigms of selective attention, it was shown that self-relevant stimuli, which are completely task-irrelevant, impeded responses to task-relevant stimuli. For example, response times in a name-identification task were slower when participants’ own faces were presented as flankers compared to when neutral faces were presented as flankers (Brédart, Delchambre, & Laureys, 2006). Similarly, in a negative-priming paradigm, the participants’ own names as distractors in a prime display slowed down prime performance on a non-self-relevant target, while no negative-priming effect was obtained for these self-relevant stimuli, suggesting that one’s own name does attract attention unintentionally, but ignoring it is somehow hindered, preventing after-effects of ignoring (Frings, 2006). Furthermore, participants’ own names resulted in a larger cuing effect in a visual-search task, and, in an antisaccade task, participants responded more slowly when they had to prevent their attention from being captured by their own name than from a neutral name (Alexopoulos, Muller, Ric, & Marendaz, 2012). Besides these indications of the attention-grabbing potential of self-relevance, diverse studies suggest shown that self-relevant stimuli bypass attentional thresholds more easily than stimuli which are not connected to the self as, for example, the own name was the only stimulus noticed when presented to the to-be-ignored ear in a dichotic-listening task (Moray, 1959) and the own name survived the attentional blink significantly better than another name (Shapiro, Caldwell, & Sorensen, 1997).

Nevertheless, this own-name effect seems to depend on the individual working-memory capacity (Conway, Cowan, & Bunting, 2001) and an affective priming effect for participants' initials when presented before positive targets depended significantly on participants' explicit self-esteem (Wentura, Kulfanek, & Greve, 2005), suggesting that self-prioritization can be affected by interindividual differences.

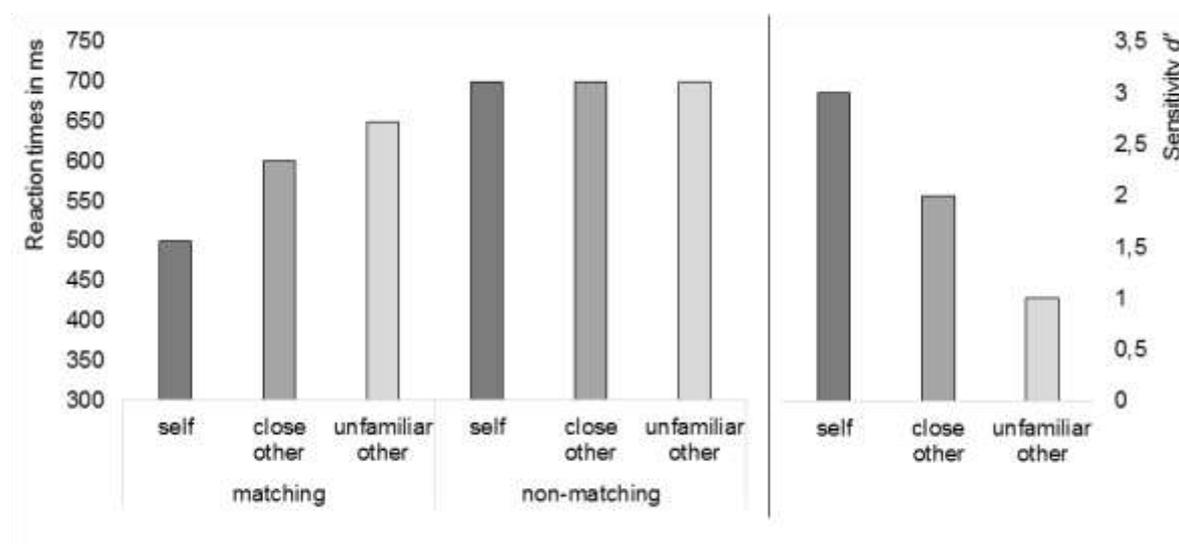
Yet, when assessing the effects of self-relevance, a major problem concerned the used material. That is, typically the participants' names, initial letters, or pictures of their faces were used in the self-relevant condition and were compared to non-familiar names, letters or faces. Consequently, self-relevance was confounded with familiarity as the self-relevant, but not the non-self-relevant stimuli were highly familiar and overlearned and thus the obtained effects could alternatively be attributed to familiarity. Considering that stimulus familiarity is discussed to play a role in selective-attention paradigms (see, e.g., Brédart, Delchambre, & Laureys, 2006), an experimental (rather than a quasi-experimental) variation of the stimulus material in the self-relevant and non-self-relevant condition would be ideal. In this context, to resolve the previous confound, a new paradigm was introduced in which formerly neutral stimuli are associated with the self, a familiar person, or a neutral instance (Sui, He, & Humphreys, 2012) and a robust prioritization of this newly acquired self-association can be measured. As this paradigm is used in all of the articles enclosed in this dissertation, it is described in detail in the following chapter.

## **2. The matching paradigm of self-prioritization**

As already mentioned, in the matching paradigm (MP), which is a computer-based experimental paradigm, formerly neutral, arbitrary stimuli are associated with three labels within a short learning sequence. The first label is the participants self ("You"), the second represents one person which is close to the personal self (e.g., "Your mother"), and the third is a neutral instance ("A stranger"). That is, the participant is instructed to memorize the associations, which are presented on the screen, and is informed that he/she will be asked about these associations later in the course of the experiment. For example, one participant might read: "You are the triangle. Mary [the name of the participant's best friend] is a square. And a stranger is represented by a circle." After this learning phase, a practice phase follows in which combinations of the presented labels and stimuli appear on the screen shortly one after another. The participant's task is to indicate whether the presented combination matches one of the previously learned associations or not. In the practice phase, the participant typically

receives feedback as to whether each given matching decision was correct, wrong or too slow (response time criterion typically above 1,500 ms). Subsequently, a testing phase follows which is congruent to the practice phase except that no more feedback is provided (at least not more than ‘too slow-feedback’). In the testing phase, response times and accuracy rates are measured.

Implementing the MP, it has been repeatedly found that participants respond more quickly and more accurately in matching trials with the self-associated stimulus compared to matching trials with one of the other stimuli, indicating a self-prioritization effect (SPE; Sui et al., 2012; Sui, Rotshtein, & Humphreys, 2013; Schäfer, Wentura, & Frings, 2015). That is, only in matching trials (i.e., in trials in which the label-shape combination matches one of the previously learned associations) responses are influenced by the self- vs. other-association of the shapes, whereas no such effect occurs in non-matching trials. For a graphical presentation of the typical data pattern in the MP see Figure 1.



**Figure 1.** The typical data pattern of reaction times and the accuracy measure  $d'$  in the matching paradigm as a function of stimulus association (and matching condition for the reaction times).

The interaction of stimulus association and matching condition indicates that the SPE cannot solely be explained by features of the self-relevant label “You” – which might indeed be, for example, more familiar than the label “stranger” – as in non-matching trials responses are neither influenced by the stimulus association (averaged for the associated stimulus) nor by the label (averaged for the used labels). In the same vein, accuracy rates are typically analyzed by calculating the sensitivity index  $d'$  for each stimulus condition in that means for each

stimulus are compared, irrespective of the label which was presented with the stimulus in a given trial (and thus already takes the matching condition into account, see Figure 1). Accordingly, a higher sensitivity rate in trials with the self-associated stimulus cannot be attributed to the presentation of the self-relevant label “You”. Due to the neutrality of the associated, arbitrary stimuli, the SPE seems to reflect a prioritization of newly acquired self-associations independent of the used material (for the effect’s independence of word concreteness, frequency, and length, see also Sui et al, 2012).

Until now, the SPE has been generalized from visual perception to action (Frings & Wentura, 2014) as well as to other sensory modalities (Schäfer, Wesslein, Spence, Wentura, & Frings, 2016) and neural correlates were identified (for details, see Sui et al., 2013). Additionally, in order to assess the underlying processes of the SPE, effects of reward association in the MP were investigated, challenging the assumption that self-relevance is inherently rewarding (Northoff & Hayes, 2011). Remarkably, the results indicate parallels but also differences between the effect of rewarding stimuli and the SPE, contradicting that the prioritization of self-relevant content is solely caused by the underlying rewarding structure of self-associations (Sui & Humphreys, 2014; Sui, Yankouskaya, & Humphreys, 2015).

Besides, in the first studies using the MP, perceptual differences due to the self-association were suggested to explain the SPE. That is, several findings were interpreted as evidence for a perceptual advantage of self-relevant stimuli comparable to the perceptual advantage of physically salient stimuli. For example, in their introductory paper, Sui and her colleagues (2012) assessed the SPE’s dependence on contrast degradation, which is assumed to modulate early stages of stimulus processing, and found an interaction effect of the SPE with contrast degradation, which was taken to indicate that self-associations influence stimulus processing on very early stages. Additionally, in a global-local task, a comparable effect of self-associated distractors (i.e., a shape which was previously associated with the self) and perceptually salient distractors (i.e., a red shape on black background) on response times as well as on functional magnetic resonance imaging (fMRI) data was found (Sui, Liu, Mevorach, & Humphreys, 2013). However, several other studies failed to demonstrate evidence that perceptual processes underlie the SPE, rather emphasizing the role of higher-order processes. Thus, meanwhile, the SPE is discussed in terms of a learning advantage for self-relevant new associations. In this context, in one study the amount of integration of the labels and stimuli was examined by presenting either one or two stimuli while participants were instructed to indicate the corresponding label and by measuring redundancy gains, that is a benefit when responding to two redundant stimuli. The results revealed two self-associated stimu-

li to cause greater redundancy gains than two other-relevant stimuli, indicating a stronger integration of self-relevant content compared to the integration of non-self-relevant content (Sui & Humphreys, 2015). Further, a learning disadvantage of other-relevant associations in comparison to self-relevant associations is assumed based on the finding that the SPE vanished when supportive feedback (via the so-called differential outcome procedure which is assumed to facilitate the learning of difficult associations) was given in the other-relevant categories but not in the self-relevant category (Fuentes, Sui, Estévez, & Humphreys, 2015). Additionally, the assessment of a prioritized initial processing of self-associated stimuli via an advantage of gaining access to visual awareness did not show any differences between self- and other-associated stimuli (Stein, Siebold, & van Zoest, 2016).

Summarizing the results concerning effects of self-relevance on matching decisions, the MP can be seen a useful tool to examine self-relevance effects independent of the stimulus material as well as in various sensory modalities and, above that, to gain insights on the processes underlying self-prioritization. Hence, the dissertation at hand includes several studies implementing the MP in order to investigate the generation of self-associations and how such self-associations influence our perception in everyday life.

### **3. Investigating self-representations**

As highlighted, a huge amount of research supports the assumption that self-relatedness has a substantial influence on stimulus processing. However, it remains unclear how exactly self-relatedness determines which stimulus is processed in what manner and how the effects of self-relatedness interact with effects of other attention-guiding stimulus characteristics. Considering the importance of identifying general mechanisms which guide attention and perception it is useful to use the MP to assess how self-representations are generated (i.e., how stimuli are integrated into the self-concept and which content is actually selected for integration) and further to assess how self-associations influence stimulus processing.

In the dissertation at hand, the mentioned open research questions are experimentally approached. A primary aim of this dissertation is to provide a comprehensive understanding of the self as a complex, individual *self-representation* and to define the effects of this self-representation on different levels. To this end, in a first step, potential influences on stimulus processing in the MP other than those which are caused by the self-relevance of particular stimuli were assessed, aiming at a deeper understanding of relevant cognitive processes in the MP as it is used throughout all studies in this dissertation (chapter 3.1.). In a next step, under-

lying mechanism for building self-associations were assessed in order to gain insights on the process of associating stimuli to the self and to find out about the structure of self-representations (chapter 3.2.). Furthermore, several experiments were conducted to evaluate the SPE's dependence on specific perceptual characteristics of the associated stimulus, giving a hint about which content is integrated into the personal self-representation (chapter 3.3. and 3.4.). Considering the so far available findings about self-representations, in a continuing study the effects of self-representations were examined and compared to other attention-guiding effects in order to qualify and differentiate the influence of self-associations on stimulus processing (chapter 3.5.).

The dissertation at hand is based on a set of five articles, in detail, three papers, which have been published in peer-reviewed journals, and two manuscripts, which are submitted for publication. These articles are appended to this dissertation in the order in which they are discussed in what follows.

### **3.1. Salience effects in the MP: Something special about the self?**

Schäfer, S., Wentura, D., & Frings, C. (2016). *Salience Effects in Self-Prioritization*. Manuscript submitted for publication.

As the MP has only recently been introduced, a first aim was to examine whether the SPE could be attributable to factors which are not related to self-relevance but also influence task performance in the matching task. Note that stimulus processing in binary forced-choice tasks has often been shown to be influenced by several parallel processes, many of which could potentially also operate in the MP. In detail, given the multiple-pairs matching decision participants' have to work on when confronted with the MP, and considering that the SPE is described as considerably better performance in one of the presented pairs, an important question here was whether the prioritization of one pair was exclusively due to the self-relevance of this pair or whether other features could cause a pop-out of this particular stimulus-label pair. Due to the requirement to simultaneously memorizing several pairs, participants could alternatively constantly select one pair, which is somehow special or salient, resulting in a prioritization which cannot explicitly be explained by self-relevance.

Thus, the first article enclosed in this dissertation describes three experiments which were conducted to determine whether it is a typical characteristic of the matching task that one pair (which does not necessary need to be self-relevant) stands out in performance. Therefore, several pairs were built by associating four different geometric forms to one outstanding,

*salient* label or to one of various non-outstanding labels. In the following matching task (using the typical experimental setup of the MP), pairings of the four shapes and labels were presented and a prioritization effect due to salience differences was tested. Additionally, when a self-relevant label was assigned to one of the shapes, the SPE was measured. The results were clear-cut in showing a prioritization of the *salient* pair in each of the three reported experiments. Yet, remarkably, a significant SPE beyond the prioritization due to salience was additionally obtained (in those experiments including a self-relevant pairing). Hence, the three studies presented in the first article revealed an influence of a general salience-triggered process in the MP, but also an effect of self-relevance which goes beyond the recoding of perceptually salient content.

### **3.2. The generation of the self: Underlying mechanism for building self-associations**

Schäfer, S., Frings, C., & Wentura, D. (2016). About the Composition of Self-Relevance: Conjunctions not Features are Bound to the Self. *Psychonomic Bulletin & Review*, 23, 887-892. doi:10.3758/s13423-015-0953-x

A substantial aspect of the SPE in the MP is that arbitrary stimuli are associated with the self or with non-self-relevant instances. A prioritization of trials with the self-associated stimulus in the following matching task indicates an integration of a formerly neutral stimulus into the self-representation. A potentially comparable, automatic binding of stimuli to different content is known from the literature on stimulus bindings (see, e.g., Kahneman, Treisman, & Gibbs, 1992; Hommel, 2004). In theories on so-called *object files* or *event files* it is assumed that, once they have been processed, stimuli are “stored” in a kind of file. Additionally, specific information associated with the stimulus is assumed to be stored, for example particular action-relevant features of the stimulus, just like the response which was performed on the stimulus and even irrelevant, distracting information which was present during the performance. The stimulus-stimulus or stimulus-response bindings are postulated to be binary (i.e., single features are separately bound to the same stimulus) and to arise rather automatically with the goal to facilitate action control (for an overview, see Henson, Eckstein, Waszak, & Frings, 2014).

It seems plausible to assume that the building of self-associations triggering the SPE is based on similar stimulus-stimulus or stimulus-response bindings, aiming at a facilitation of self-referential actions. If this were true, then self-associations would consist of *binary* bind-

ings, meaning that single features of a neutral stimulus would be bound to the self separately. Consequently, if single features were associated with the self and if these self-associations then cause a prioritization in the matching task, then single features of the self-associated stimulus should actually be prioritized. Note, however, that a prioritization of single features would result in an unspecific prioritization of a great number of stimuli (namely, any stimulus sharing at least one feature with the self-associated stimulus) rather than efficient prioritization of those feature conjunctions associated with the self, making the assumption of binary bindings rather unlikely.

In order to assess whether separate features or feature conjunctions are bound to the self, in the second article enclosed in the dissertation, feature conjunctions were instructed to belong to the self. In the subsequent matching task, no indication for a prioritization of separate features was found (as none of two characteristics of bindings were found, neither the binary structure nor processing costs for partial repetitions of the conjunction). Regarding this non-indication of a prioritization of separate features, it was concluded that whole feature conjunctions, rather than separate features, become associated with the self, reflecting a functional, specific prioritization due to self-relevance.

### **3.3. Assessing the level of self-prioritization: Evidence for a conceptual self**

Schäfer, S., Wentura, D., & Frings, C. (2015). Self-prioritization beyond perception. *Experimental Psychology*, 62, 415-425. doi:10.1027/1618-3169/a000307

Particular effect of self-relevant material like the participant's own name or picture, suggest a selection of self-relevant content on a very early processing stage. For example, the above-mentioned own-name effect in the dichotic-listening paradigm and the attentional-blink paradigm is taken as evidence for an automatic, sub-conscious process of self-prioritization (Alexopoulos et al., 2012). Accordingly, the SPE in the MP was discussed to represent a perceptual advantage for self-relevant associations (see chapter 1.1.). Nevertheless, whenever self-relevance was confounded by familiarity in previous experiments (using the own name or picture), this confound may have led to the observation of an effect on an early processing stage. Moreover, higher-order effects of self-relevant material, like memory advantages (see e.g., Cunningham et al., 2008) as well as non-perceptual effects of newly acquired self-associations (Fuentes, et al., 2015; Stein, et al., 2016) allude that the SPE may not represent a perceptual bias, but rather a prioritization at later processing stages.

In order to gain a deeper understanding of whether self-associations mainly influence early perceptual stimulus processing or whether there is a higher-order, conceptual component of self-prioritization, in the third article included in this dissertation, the MP was used to associate (semantic) concepts with the self. Therefore, in a first study, the self, a close person (i.e., the mother), and a neutral instance were to-be-associated with one of three geometric shapes, and in the following matching task, these shapes were presented with varying or with constant features. Remarkably, the observed SPE was comparably strong when a prototypical white shape was presented (constant features) and when the shapes were presented with varying colors, orientations, and hatchings (varying features). In a second study, participants learned associations of three labels with three instruments (i.e., a piano, a guitar, and a flute), and in the following matching task the instruments were represented by either a picture or a tone. A significant SPE was observed independent of whether the representing stimulus was visually or auditorily presented. In sum, the repeated finding of a SPE independent of perceptual features of the associated stimulus was interpreted as evidence for an association of abstract concepts with the self and for a conceptual component of self-prioritization.

### **3.4. The meaning of self-prioritization in the senses: The generalization of a conceptual effect**

Schäfer, S., Wesslein, A. K., Spence, C., Wentura, D., & Frings, C. (2016). Self-prioritization in vision, audition, and touch. *Experimental Brain Research*, 234, 2141-2150.

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An important question when assessing effects of self-relevance deals with the generation of a core self-representation. Assuming a rather stable representation of the self, one can ask which processes contribute to the generation and adaption of the self-representation. In the field of self- and ownership-research, certain of publications show that in particular somatosensory input and the integration of input from different sensory modalities influence how we define the borders of our self (for an overview, see Gallace & Spence, 2014).

Hence, in the fourth article included in the dissertation, the generalization of the SPE from visual perception to auditory and tactile perception was assessed. Therefore, the self, a close person, and a neutral instance were associated with either visual (to measure the size of the typical SPE as a baseline), auditory, or vibrotactile stimuli. Remarkably, response times and sensitivity data revealed the typical data pattern in all three sensory modalities. Moreover, a comparison of the SPE across the modalities yielded no evidence for a difference in the size

of the three SPEs, but suggested the effects' independence of the sensory modality. Thus, comparable SPEs in different sensory modalities implied that input from different senses can flexibly be integrated into the self-representation, indicating a complex, flexible, ongoing process. Above that, the results revealed further evidence for the before postulated higher-order component of self-prioritization, which is rather conceptual and not dependent on perceptual specificity.

### 3.5. Defining the self-effect: Selection mechanism or learning advantage?

Schäfer, S., Wentura, D., & Frings, C. (2016). *'I' versus 'death': Disentangling effects of self-relevance and negative valence*. Manuscript submitted for publication.

In the light of the repeatedly found effects of self-associations, one could argue that self-relevance represents a general selection mechanism guiding attention automatically. Comparable attention-guiding effects are known from highly valent stimuli, which distract attention from relevant stimuli and capture attention constantly (for a review, see, e.g., Yiend, 2010). In detail, highly negative stimuli have been found to cause strongest effects, possibly indicating the functionality to detect negative stimuli in the surrounding (Kahan & Hely, 2008). Accordingly, in the field of attentional-capture research, a frequently discussed debate handles the question whether only highly negative, threatening stimuli guide attention – reflecting the so-called *threat-detector hypothesis* – or whether attention is allocated to any stimulus which is relevant for a person – reflecting the so-called *relevance hypothesis* (see, e.g., Wentura, Müller, & Rothermund, 2014).

Thus, aiming at a substantial understanding of the impact of self-relevance on attention and also at a clarifying contribution to the ongoing debate about attention-allocation mechanisms, in the fifth article enclosed in this dissertation, performance in response to self-relevant stimuli was compared to performance in response to highly negative stimuli. Further, the effects were compared in two different paradigms in which the stimulus meaning (self-relevant vs. negative) could either be varied on the task-relevant dimension or on a task-irrelevant dimension. In detail, self-relevant and negative stimuli were contrasted in the MP, which is sensitive to effects of self-relevance, and in the emotional Stroop paradigm, which is typically used to assess effects of negative valence. Here, different results would imply contrary interpretations: comparable effects of self-relevance and negative valence in both tasks would speak in favor of the relevance hypothesis, whereas different effects, more precisely a dominant effect of self-relevance in the MP and a dominant effect of negative valence in the

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emotional Stroop paradigm, would speak in favor of an extension of the relevance hypothesis, assuming independent factors which can guide attention in a different manner. The results of both studies were clear-cut and indicated a dissociation of the effects of self-relevance on the one hand and of negative valence on the other hand. Moreover, a dominant effect of self-relevance occurred when stimulus meaning was varied on the task-relevant dimension (i.e., in the MP where the matching decision has to be performed according to the meaning of the label), suggesting a learning advantage for self-associations, but not for negative-associations, whereas a dominant effect of negative valence occurred when stimulus meaning was varied on the task-irrelevant dimension (i.e., in the emotional Stroop paradigm where the meaning of the presented word is completely unrelated), pointing out an attention-guiding effect of valence, but not of self-relevance.

#### **4. Original Manuscripts**

The following section comprises the five articles underlying the present dissertation in the order in which they are presented above. Note that the paging numbers on the following pages are those from the original manuscripts.

Saliency effects in self-prioritization

RUNNING HEAD: Saliency effects in self-prioritization

## **Saliency Effects in Self-Prioritization**

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**Abstract**

The prioritization of self-relevant information has been shown in different paradigms tapping selective attention. Recently, in a new paradigm, formerly neutral material was associated either with the self, a familiar person, or a neutral instance and in a following matching task the self-associated pairings were prioritized (Sui, He, & Humphreys, 2012). In order to test whether this self-prioritization might be due to saliency differences in the stimulus material and not due to self-relevance per se, we manipulated the saliency asymmetry in the matching paradigm. Three experiments provided evidence that attentional asymmetries influenced reaction times and signal detection indices in that more salient stimuli elicited faster responses and better detection rates. Yet, the data also showed that the self-prioritization effect remained reliable when controlling for the influence of saliency. The results suggest that saliency asymmetries do play a role in the matching paradigm and should be considered when assessing effects of self-relevance. However, at the same time the results showed that the self-prioritization effect in the matching task is more than just the recoding of perceptually salient content.

Keywords: self-prioritization, attentional processing, saliency

### **Saliency Effects in Self-Prioritization**

The prioritization of self-relevant information has been shown in different paradigms of selective attention. Quite recently, a new paradigm was introduced to assess effects of self-associations on matching decisions (Sui, He, & Humphreys, 2012). In detail, the authors introduced a paradigm (the “matching paradigm” in the following) in which participants learn associations of three geometric shapes with different labels, namely with their own self, a familiar person (e.g., a friend), and a stranger. In the subsequent task, pairings of shapes and labels are presented and participants have to quickly decide whether the presented pairing matches one of the previously learned associations or not. Reaction times (RTs) and the signal-detection sensitivity measure  $d'$  show a self-prioritization effect (SPE) in that verifying self-relevant matching trials is faster and more accurate than verifying non-self-relevant matching trials.

Note that, until then, in self-prioritization research, participant’s own name, a picture of his or her face, or autobiographical information had been used as self-relevant information. Consequently, the self-relevant stimuli had been highly overlearned and were more familiar compared to the used non-self-relevant stimuli (i.e., other names or faces). Considering this confound, by forming associations of formerly neutral stimuli with the self, the newly introduced matching paradigm allows, for the first time, to assess effects of self-relevance independent of stimulus frequency. The SPE in the matching paradigm has been replicated several times (e.g., Fuentes, Sui, Estévez, & Humphreys, 2015; Schäfer, Frings, & Wentura, 2016; Sui & Humphreys, 2014), has been generalized from visual perception to action (Frings & Wentura, 2014) as well as to other stimulus modalities (Schäfer, Wesslein, Spence, Wentura, & Frings, in press) and neural correlates have been detected (Sui, Rotshtein, & Humphreys, 2013). Thus, as this paradigm seems to be an important tool to measure effects of stimulus relevance and therefore could be used frequently in the future, the operating processes in this task should be examined.

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We argue that the SPE might be caused by two different processes: First, a process which is indeed specific for self-related stimuli. Second, by virtue of a more general process that is triggered at the onset of the experiment by the most salient member of the set of labels used in the experiment, which is often (but not always and not necessarily) the self-relevant one. As said, the first process is assumed to be a process which is specific for self-related stimuli. Merely, Sui and her colleagues concede a similar effect for reward-related stimuli (see Experiment 4B in Sui et al., 2012) but even this result is discussed given the backdrop of an intimate relationship between self- and reward-processing. In the remainder of the text, we will refer to this first process as a *genuine self-related process*. The second process is a more general process. Described at an abstract level, the SPE means that in a multiple-pairs matching task one designated pair is associated with considerably better performance. With regard to this pattern, one might ask whether it is a typical characteristic of this task that one pair stands out in performance, irrespective of whether the pair is self-related or not, that is, a *general salience-triggered process*.

The following everyday example might help to give some initial plausibility to why this might be the case: Imagine that you are on a party and the host introduces to you four persons that are standing close to you. It might appear overtaxing to immediately create four strong face-name bindings. However, it might be overtaxing as well to mentally juggle with four names and four faces, always trying to recollect the assignment episode whenever necessary during the next minutes. Thus, if at least one name stands out (e.g., it is a rare one or is your best friend's name), you will easily associate it with the corresponding person, thereby immediately reducing the remaining "juggling" problem.

Going back to the matching task, an outstanding, salient label might be more easily bound to the assigned shape and therefore correct matching decisions will be faster. Thus, the most salient label in the matching task might lead to a better label-shape binding and, hence, it shows better performance. In the published experiments with the matching paradigm,

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participants learn multiple label-shape assignments and only one assignment is self-relevant whereas two (or three) other assignments are not self-relevant. Consequently, it might typically be the self-relevant label which is the salient one. If so, at least part of the self-prioritization effect is due to a more general principle, namely saliency. Note that saliency-based re-interpretations of reaction-time effects were found for other paradigms as well (Chang & Mitchell, 2009; Rothermund & Wentura, 2004; Wentura, 2000).

Thus, in this article, we are going to assess the question whether saliency of stimuli might contribute to prioritization effects in the matching task. In order to do so, three experiments were conducted. Experiments 1a and 1b are designed to directly disentangle the contribution of the genuine self-prioritization process and the saliency-triggered component. In Experiment 1a, a matching task was conducted with one self-relevant stimulus (the pronoun “I”) and three non-self-relevant stimuli (i.e., three nouns). According to the saliency assumption, here the self-relevant stimulus is outstanding not only because it is the only self-relevant stimulus one but also because it is obviously the only pronoun among three nouns. Thus, we hypothesize the occurrence of the SPE in Experiment 1a which would indicate that the experimental setup reliably elicits the SPE. In Experiment 1b, the methods were equal to those in Experiment 1a except that the pronoun “I” was replaced by the pronoun “he” which is no longer self-relevant but still salient as it is the only pronoun. Here, we expect a prioritization effect for the pronoun which, however, might be less pronounced than the corresponding effect in Experiment 1a as the salient pronoun in Experiment 1b is not self-relevant. Finally, in Experiment 2 the saliency pattern was inverted so that only one noun and three pronouns were used as labels and therefore the noun appeared as the outstanding label. One of the pronouns, however, was self-relevant (“I”) to assess self-prioritization in a context where (presumably) the self-relevant label is not the outstanding stimulus. In Experiment 2 we predict a prioritization of the noun (representing the salient label) and, above that, a SPE due to the genuine self-related prioritization process. Note that in all experiments described

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here, four assignments were used in order to maximize salience effects between nouns and pronouns. Thus, a SPE in Experiment 2, that is, a SPE with potentially strong salience effects working against it, would significantly reinforce the interpretation of effects of self-relevance in the matching paradigm.

### Experiment 1

In the first experiment, participants learned one *self-relevant* pronoun assignment (in Experiment 1a represented by the self-relevant pronoun “I”) or one *non-self-relevant* pronoun assignment (in Experiment 1b represented by the pronoun “he”) and in each case three non-self-relevant assignments (represented by three nouns). Thus, according to our hypothesis, the pronoun appears as the salient label in both experiments; hence a prioritization effect should be observed in both experiments. However, due to a genuine self-related process, the prioritization effect in Experiment 1a should be larger compared to the effect in 1b.

### Method

**Participants.** In Experiment 1a, 24 students from the University of Trier (21 female) took part in the experiment receiving course credit. Median age was 22 years (ranging from 18 to 27) and all participants had normal or corrected-to-normal vision. In Experiment 1b, also 24 students from the University of Trier (22 female) took part in the experiment receiving course credit. Median age was 23 years (ranging from 18 to 25) and they all had normal or corrected-to-normal vision. The mean error rate of one participant constituted an outlier according to Tukey (1977) when compared to the sample distribution of the mean error rates of all participants so that the data from this participant were discarded, resulting in a total sample size of 23 participants for Experiment 1b.

**Design.** The experiments comprised a 2 (matching condition: *matching* vs. *non-matching*) x 4 (label: pronoun [*I* in Exp. 1a, *he* in Exp. 1b] vs. *stranger* vs. *nothing* vs.

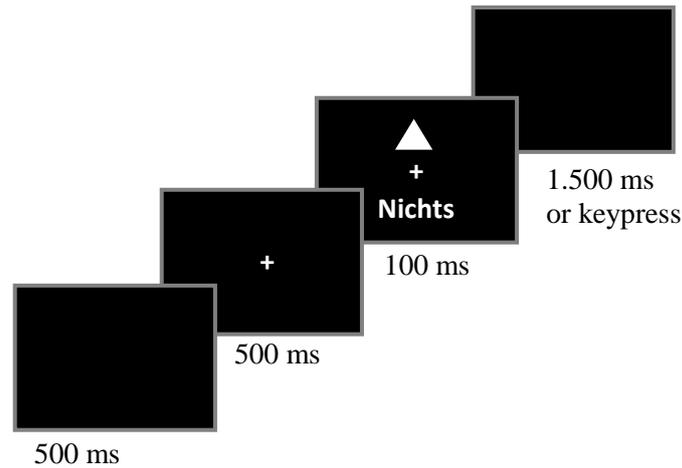
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*mother*) repeated-measures design. The assignment of label and shape was balanced across participants following a Latin-square design.

**Material and apparatus.** The experiments were conducted using standard PCs with TFT monitors that had a display resolution of 1,280 x 1,024 pixels, standard German QWERTZ keyboards and by using E-Prime 2.0 software. Stimuli were the German words *Ich* [I] or *Er* [he], *Fremder* [stranger], *Nichts* [nothing] and *Mutter* [mother] presented in white on black background. The geometric shapes were square, circle, triangle, and cross. Words were presented in Courier New, with a viewing distance of 60 cm resulting in a visual angle of about 0.57°. All stimuli were presented at the screen center, the shape at a visual angle of 10.95° from the upper border of the screen, a fixation cross at 14.25° and the label at 17.06°. The geometric shapes were presented subtending 3.06° x 3.06° visual angle.

**Procedure.** Participants were tested individually in soundproofed rooms. Task instructions were given on the screen and summarized by the experimenter. In the first phase of the experiment, assignments of the given labels and shapes were shown on the display for 60 seconds. In order to stay close to the original experiment by Sui and colleagues (2012), the particular label-shape assignments were presented in written form. For a particular participant this assignments might read: “I am [He is] the square. A stranger is the circle. Nothing is the triangle. The mother is the cross.” Participants were instructed to place the index finger of the left hand on the S-key (non-matching response) and the index finger of the right hand on the L-key (matching response).

In the second phase of the experiment, the matching task was passed and here each trial started with a 500 ms presentation of a black screen, followed by a fixation cross for 500 ms, a pairing of one label and one shape for 100 ms and another black screen until the participant responded or 1,500 ms had elapsed (see Figure 1).



**Figure 1.** Sequence of events in a trial with a neutral label, the German word *Nichts* [nothing], and the triangle as the shape (stimuli are not drawn to scale).

Participants' task was to judge whether the displayed label-shape pairing corresponded to one of the initially learned assignments or not. One experimental session consisted of a practice block with 24 trials and an experimental block with 192 trials. In both, the practice and the experimental block, each label was presented in one quarter of the trials, half of it with matching and half with non-matching assignments (resulting in 24 trials per condition in the experimental block). Trials were presented in random order.

## Results

Only correct responses with RTs above 200 ms and below 1.5 interquartile ranges above the third quartile of the overall RT distribution (Tukey, 1977) were used for the RT analysis. Averaged across participants, 85.8 % (Exp. 1a) and 86.5 % (Exp. 1b) of the trials were selected for RT analysis. 10.9 % (Exp. 1a) and 10.1 % (Exp. 1b) of the trials were excluded because of erroneous responses and 3.3 % (Exp. 1a) and 3.4 % (Exp. 1b) due to the RT-outlier criteria. Mean RTs and error rates are shown in Table 1. All effects referred to as statistically significant throughout the text are associated with  $p$  values less than .05.

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**Table 1.** RTs in milliseconds and error rates (in %) as a function of matching condition (*matching* vs. *non-matching*) and shape association, for the Experiments 1a, 1b and 2. Standard deviations in parentheses.

<i>Experiment</i>	<i>Shape Association</i>	<i>Matching Condition</i>			
		<i>Matching</i>		<i>Non-matching</i>	
		<i>RTs</i>	<i>Error Rates</i>	<i>RTs</i>	<i>Error Rates</i>
<i>1a</i>	<i>I</i>	486 (78)	7.8 (8.8)	607 (81)	7.8 (7.2)
	<i>Stranger</i>	569 (120)	14.8 (10.2)	600 (81)	8.3 (6.0)
	<i>Nothing</i>	618 (133)	18.2 (12.6)	602 (79)	11.8 (10.5)
	<i>Mother</i>	490 (69)	6.3 (8.2)	613 (83)	12.2 (10.7)
<i>1b</i>	<i>He</i>	514 (75)	7.1 (6.1)	605 (101)	9.2 (10.2)
	<i>Stranger</i>	578 (136)	16.1 (14.5)	600 (94)	11.6 (10.0)
	<i>Nothing</i>	565 (113)	14.7 (12.3)	595 (105)	11.1 (7.4)
	<i>Mother</i>	472 (76)	5.4 (5.2)	594 (94)	5.3 (6.2)
<i>2</i>	<i>I</i>	482 (91)	8.7 (6.7)	599 (129)	11.0 (10.5)
	<i>He</i>	534 (107)	8.9 (9.5)	586 (100)	8.9 (9.0)
	<i>She</i>	522 (111)	8.7 (10.5)	592 (103)	9.3 (10.0)
	<i>Room</i>	491 (96)	9.5 (9.9)	589 (98)	7.4 (6.5)

**Experiment 1a.** In a first analysis, a 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape: *self-* vs. *stranger-* vs. *nothing* vs. *mother-associated*) repeated-measures MANOVA was computed with mean RTs as the dependent variable. Both main effects were significant,  $F(1, 23) = 51.49, p < .001, \eta_p^2 = .69$ , for matching condition, and  $F(3,$

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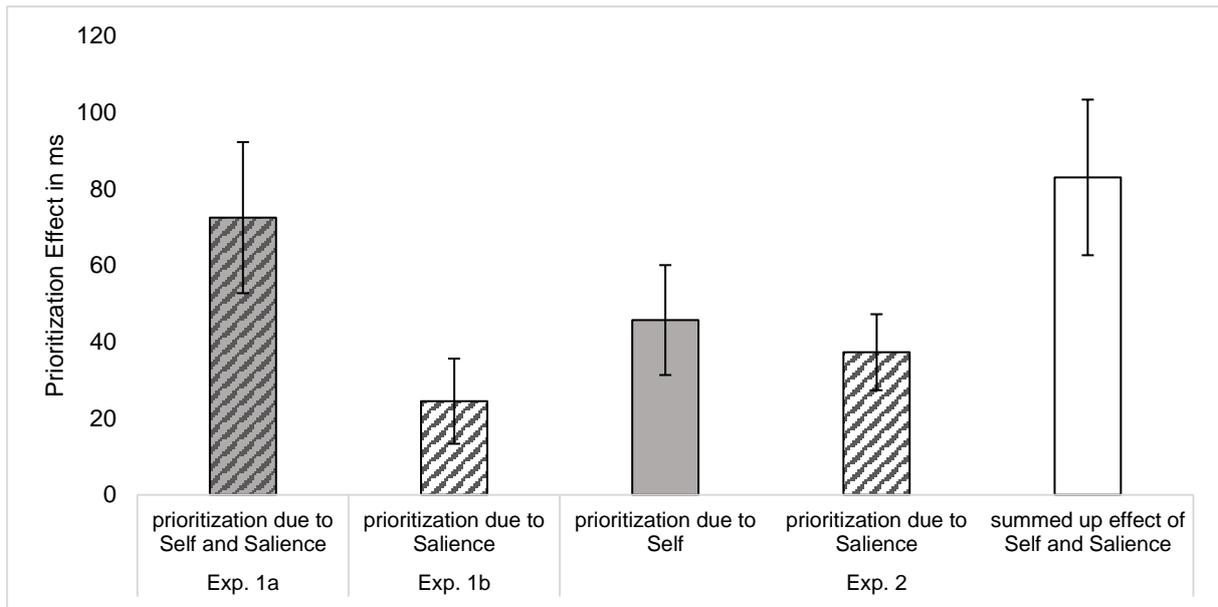
21) = 9.93,  $p < .001$ ,  $\eta_p^2 = .59$ , for shape, suggesting faster responses in matching trials and different response times according to the association of the shape. The interaction was also significant,  $F(3, 21) = 10.61$ ,  $p < .001$ ,  $\eta_p^2 = .60$ , showing that the effect of the shape was different in matching and in non-matching trials.

According to the significant interaction of matching condition and label and in accordance to Sui and colleagues (2012), prioritization was further analyzed in the matching trials. Comparing mean RTs in the matching condition in a one-factorial repeated-measures MANOVA with four levels (shape: *self-* vs. *stranger-* vs. *nothing* vs. *mother-associated*) revealed a significant main effect,  $F(3, 21) = 11.56$ ,  $p < .001$ ,  $\eta_p^2 = .62$ . This suggests that the association of the shape affects response times in matching trials. The SPE is typically computed as the difference between mean RTs in matching trials with the self-relevant shape (i.e., the shape associated with the label “I”) and the averaged RTs in matching trials with the non-self-relevant shapes (i.e., the shapes associated with the labels “stranger”, “nothing”, or “mother”). This difference is indicated by the first Helmert contrast, which was significant,  $F(1, 23) = 13.47$ ,  $p = .001$ ,  $\eta_p^2 = .37$  (see Figure 2), indicating faster responses in matching trials with the self-associated shape compared to matching trials with a non-self-associated shape. No such effect was measured in a one-factorial repeated-measures MANOVA with non-matching trials,  $F(1, 23) = 1.35$ ,  $p = .286$ ,  $\eta_p^2 = .16$ .<sup>1</sup>

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<sup>1</sup> As can be seen in Table 1, the label “mother” produces a result pattern similar to the self-related pronoun (in both experiments). This comes to no surprise since similar results were found by Sui and colleagues (2012) and are typically explained by the affinity of this label to the self as a kind of „extended self”. We will not further elaborate on this, since this detail is not focal to our argumentation

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**Figure 2.** Prioritization effects of either the self-relevant trials presented as the salient stimulus (Exp. 1a), the non-self-relevant trials presented as the salient stimulus (Exp. 1b), or of both, the self-relevant trials presented as the non-salient as well as the non-self-relevant trials presented as the salient stimulus (Exp. 2, respectively). Error bars depict standard error of the mean.

Error rates were analyzed computing signal detection-sensitivity indices for each shape condition in order to consider the individual response criterion. Correct responses in matching trials were considered hits, while erroneous responses were considered missings. In non-matching trials, correct responses were considered correct rejections and erroneous responses were considered false alarms. Following the log-linear approach to account for cases with 100% hits or 0% false alarms (see Hautus, 1995; Stanislaw & Todorov, 1999), we then computed the  $d'$  as a measure of sensitivity for each of the associated shapes. The resulting  $d'$  indices were submitted to a one-factorial repeated-measures MANOVA with four levels (shape: *self-* vs. *stranger-* vs. *nothing* vs. *mother-associated*). The main effect was significant,  $F(3, 21) = 8.12, p < .001, \eta_p^2 = .54$ , indicating that the sensitivity varied according to the association of the shape. The SPE as the difference between  $d'$  in the self-relevant condition and the averaged  $d'$  in the non-self-relevant conditions was also significant,  $F(1, 23) = 5.39, p = .030, \eta_p^2 = .19$ , indicating that sensitivity was higher in trials with the self-associated shape.

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**Experiment 1b.** Again a 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape: *he-* vs. *stranger-* vs. *nothing-* vs. *mother-associated*) repeated-measures MANOVA with mean RTs as the dependent variable was computed. Both main effects were significant,  $F(1, 22) = 154.74, p < .001, \eta_p^2 = .88$ , for matching condition, and  $F(3, 20) = 5.91, p = .005, \eta_p^2 = .47$ , for shape association, suggesting faster responses in matching trials and different response times according to the shape association. The interaction was also significant,  $F(3, 20) = 10.02, p < .001, \eta_p^2 = .60$ , showing that the effect of the shape association was different in matching and in non-matching trials.

Comparing mean RTs in the matching condition, a one-factorial repeated-measures MANOVA with four levels (shape: *he-* vs. *stranger-* vs. *nothing* vs. *mother-associated*) revealed a significant main effect of shape,  $F(3, 20) = 8.95, p = .001, \eta_p^2 = .57$ , suggesting that the association of the shape affected response times in matching trials. The prioritization of the non-self-relevant pronoun in this experiment indicated a salience-triggered effect independent of self-relevance. Prioritization was measured as the difference between mean RTs in matching trials in the pronoun condition (i.e., the shape associated with the label “he”) and the averaged RTs in matching trials in the noun conditions (i.e., the shapes associated with the labels “stranger”, “nothing”, and “mother”). This prioritization effect was indicated by the first Helmert contrast and was significant,  $F(1, 22) = 4.84, p = .039, \eta_p^2 = .18$ , indicating a prioritization of the non-self-relevant pronoun (see Figure 2). Again no such effect occurred in non-matching trials,  $F < 1$ .

Error rates were again analyzed by signal-detection sensitivity index  $d'$  for each shape condition, using the log-linear approach (see Experiment 1). The resulting  $d'$  indices were submitted to a one-factorial repeated-measures MANOVA with four levels (shape: *he-* vs. *stranger-* vs. *nothing* vs. *mother-associated*) which revealed a significant main effect,  $F(3, 20) = 10.55, p < .001, \eta_p^2 = .61$ , suggesting different sensitivity depending on the association of the shape. The prioritization effect as the difference between  $d'$  in the pronoun condition

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and the averaged  $d'$  in the noun conditions (first Helmert contrast), however, was not significant,  $F(1, 22) = 1.83$ ,  $p = .190$ ,  $\eta_p^2 = .08$ , not indicating a prioritization of the pronoun in sensitivity but also not revealing any indication of an accuracy-speed trade off.

**Comparison of the experiments.** In order to figure out whether there is a genuine self-prioritization effect, the prioritization effects of Experiment 1a and 1b were compared. The prioritization effect in Experiment 1a, where prioritization was due to genuine self-relevance and salience, was significantly larger than the prioritization effect in Experiment 1b, where prioritization was only due to salience,  $t(45) = 2.09$ ,  $p = .042$ ,  $d = .61$ . The same data pattern occurred in the corresponding analysis with  $d'$ ,  $t(45) = 2.64$ ,  $p = .011$ ,  $d = -.77$ . This supports that the prioritization effect in Experiment 1a depended significantly on the inherent self-relevance of the stimulus presented as the salient one.

## Discussion

In Experiment 1a, RT data and  $d'$  indices revealed a replication of the SPE in our version of the matching paradigm. Here, the self-relevant pronoun was presented as the salient label, so that the given SPE might imply a prioritization due to both, the genuine self-prioritization processes and/or the salience-triggered process. This assumption is confirmed in Experiment 1b, because RT data revealed a prioritization of a non-self-related pronoun which was presented as the salient label. Thus, these results indicate a prioritization due to salience even if no self-relevant stimulus is employed. However, as expected, the SPE in Experiment 1a is significantly larger than the salience-based prioritization effect in Experiment 1b.

In order to compare the effects of salience and self-relevance on a different route, in a next experiment the self-relevant stimulus was presented as a non-salient stimulus (to measure the SPE independent of salience effects) and a non-self-relevant pronoun was presented as the outstanding label (to measure the salience effect independent of self-relevance).

## Experiment 2

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In Experiment 2 the salience asymmetry was inverted. Now participants learned only one noun assignment and three pronoun assignments and therefore the noun assignment appeared as the outstanding label. Accordingly, the self-relevant stimulus (i.e., the pronoun “I”) was represented as part of the non-salient set so that the SPE and the salience effect could be assessed independently.

### Method

**Participants.** 24 students from the University of Trier (20 female) took part in the experiment receiving course credit. Median age was 21 years (ranging from 19 to 27) and they all had normal or corrected-to-normal vision. The mean RT of one participant and the mean error rate of another participant constituted an outlier according to Tukey (1977) when compared to the sample distribution of all participants, so that the data from these participants was excluded from the analyses, resulting in a total sample size of 22 participants.

**Design.** Experiment 2 comprised a 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape: *I-* vs. *he-* vs. *she-* vs. *room-associated*) repeated-measures design. The assignment of label and shape was balanced across participants following a Latin-square design.

**Material, Apparatus, and Procedure.** Experiment 2 was a replication of Experiment 1 with the exception that one noun and three pronouns were used as label, namely the German words *Ich* [I], *Er* [he], *Sie* [she], and *Raum* [room].

### Results

Only correct responses with RTs above 200 ms and below 1.5 interquartile ranges above the third quartile of the overall RT distribution (Tukey, 1977) were used for the RT analysis. 9.0 % of the trials were excluded because of erroneous responses and 4.1 % due to the RT outlier criteria. Averaged across participants, 86.9 % of the trials were selected for RT analysis.

In the 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape: *I-* vs. *he-* vs. *she-* vs. *room-associated*) repeated-measures MANOVA with mean RTs as the dependent

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variable the main effect of matching condition was significant,  $F(1, 21) = 122.97, p < .001, \eta_p^2 = .85$ , and the main effect of shape missed the conventional criterion of significance,  $F(3, 19) = 2.93, p = .060, \eta_p^2 = .32$ , suggesting faster responses in matching than in non-matching trials and only slightly different response times according to the association of the shape. Most important, the interaction was significant,  $F(3, 19) = 7.40, p = .002, \eta_p^2 = .54$ , suggesting that the shape association affected response times differently in matching and in non-matching trials.

Comparing mean RTs in the matching condition, the one-factorial (shape: *I-* vs. *he-* vs. *she-* vs. *room-associated*) repeated-measures MANOVA revealed a significant main effect of shape,  $F(3, 19) = 7.02, p = .002, \eta_p^2 = .53$ , indicating an effect of the shape association in matching trials. As in this experiment the SPE and the salience effect could potentially work in parallel, we conducted the two effects independently. Accordingly, the SPE was measured by the difference between mean RTs in trials with the self-associated pronoun (i.e., shapes associated with the pronoun “I”) and the averaged RTs in trials with the non-self-relevant pronoun-associated shapes (i.e., shapes associated with the pronouns “he” or “she”). This difference was indicated by a Helmert contrast and was significant,  $F(1, 21) = 10.12, p = .004, \eta_p^2 = .33$ , showing a prioritization of the self-relevant trials<sup>2</sup>. Further, the salience effect was measured by the difference between mean RTs in trials with the noun-associated shape (i.e., shapes associated with the noun “room”) and the averaged RTs in trials with the non-self-relevant pronoun-associated shapes. This difference was also significant,  $t(21) = 3.75, p =$

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<sup>2</sup> One might argue that all participants segregate the labels into salient and non-salient labels but that some of them process the noun as the salient category (i.e., because it is the only noun among pronouns) whereas others process the self-relevant pronoun as the salient category (i.e., because it is the only self-relevant category). If so, the SPE found in this experiment does not establish a genuine self-prioritization effect. However, if this assumption holds, the SPE and the salience effect will be negatively correlated. To check for this possibility, we created two completely independent effect scores (i.e., difference scores with non-shared components). To obtain independent indicators for the SPE and the salience effect, the mean RTs in matching trials with the self-associated shape or the mean RTs in matching trials with the room-associated shape, respectively, were subtracted from the averaged RTs in matching trials with the “he” or “she”-associated trials. Note that the assignment of “he” and “she” trials to either the control condition for the self-associated trials or to the control condition for the “room”-associated trials was randomly selected for each participant. The correlation of these two effects was non-significant over ten (randomly-assigned) analyses,  $.028 < r < .280; .185 < p < .898$ .

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.001,  $d = .80$ , indicating a prioritization of the salient-label trials (see Figure 2). Again, no main effect occurred in non-matching trials,  $F < 1$ .

Comparable to the analysis in Experiment 1 and 2, error rates were analyzed by signal-detection sensitivity index  $d'$  for each shape condition. In a one-factorial repeated-measures MANOVA with four levels (shape: *I-* vs. *he-* vs. *she-* vs. *room-associated*) and  $d'$  as the dependent variable the main effect was not significant,  $F < 1$ , suggesting that the sensitivity was not affected by the shape. Consequently, neither the SPE (indicated by a Helmert contrast) nor the saliency effect (indicated by a particular t-test) was significant,  $F(1, 21) = 1.50$ ,  $p = .235$ ,  $\eta_p^2 = .07$  and  $t < 1$ , respectively, indicating no prioritization, neither due to self-relevance nor to saliency but also contradicting any accuracy-speed trade off.

**Across experiments comparison.** A further analysis was conducted to assess whether the result found in Experiment 1a mirrored an additive effect of self-relevance and saliency. Therefore, the two prioritization effects in Experiment 2 (one due to self-relevance and one due to saliency) were summed up. This summed up effect and the overlapping effect of self-relevance and saliency in Experiment 1 were comparably strong,  $t < 1$ ,  $p = .713$  (see Figure 2). The same data pattern occurred in the corresponding analysis with  $d'$ ,  $t < 1$ ,  $p = .345$ .

## Discussion

In Experiment 2, RT data revealed a prioritization of the self-relevant stimulus even if this stimulus was presented as part of the non-salient set. Moreover, a prioritization of the non-self-relevant noun was found whereby this non-self-relevant noun was presented as the salient label. That is, the data confirm the assumption of an effect of saliency in the matching paradigm but, above that, indicate a SPE independent of such saliency effects.

## General Discussion

We set out to analyze whether the SPE really reflects effects of self-relevance or whether and how saliency of the material might contribute to the SPE. This is an important

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question as in principle the matching task offers new and intriguing ways for analyzing processes of self-prioritization and learning of self-associations. However, in previous experiments using the matching task, typically the self-relevant stimulus was the only pronoun presented in a group of nouns. Thus, it might be the salience and not self-relevance producing the SPE.

In a series of three experiments, an effect of salience in the matching task was measured. Particularly, presenting one stimulus from one word-type category (e.g., pronoun) and three stimuli from another word-type category (e.g., noun) repeatedly resulted in a prioritization of the single-stimulus category. Thus, there was a salience-triggered effect in that differences in the salience of the stimuli had an influence on stimulus processing in the matching task. Importantly, the data also demonstrated that there is a genuine effect of self-relevance irrespective of the salience-based effect. An effect of self-relevance is clearly shown by two important results. On the one hand, the salience effect in the matching task was significantly stronger when the outstanding stimulus was self-relevant compared to when it was neutral according to the participant's self (indicated by the difference between the prioritization effects in Experiment 1a and 1b). On the other hand, in Experiment 2, an SPE was measured even when the self-relevant stimulus appeared as the non-salient label and hence the effects of salience counteracted the SPE. Moreover, there was no difference between the summed up prioritization effects in Experiment 2 and the overlapping effect of self-relevance and salience in Experiment 1a. The additive structure of the two effects supports the assumption that the effect of salience and the effect of self-relevance are independent. Consequently, the measured prioritization effect in a typical matching task, in which the self-relevant pronoun is a salient stimulus and the other stimuli are non-self-relevant nouns, reflects additive effects of self-relevance *and* salience.

Taking a broader view, the finding of a genuine effect of self-relevance beyond an effect of salience can be a further hint in the ongoing debate about the mechanisms underlying

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the prioritization of self-relevant stimuli. Considering previous research in the matching paradigm, on the one hand, a perceptual advantage of self-associated stimuli is discussed, comparable to a prioritization of physically salient stimuli (see e.g., Exp. 4a in Sui, et al., 2012; Sui, et al., 2013). On the other hand, accumulating findings concerning a learning advantage for the self-associated pairings suggest that self-relevance does not result in an increase of perceptual salience but rather helps forming new associations (Fuentes et al., 2015; Stein, Siebold, & van Zoest, 2016; Sui, Yankouskaya, & Humphreys, 2015). Again, the assumption that self-prioritization constitutes a learning advantage might be seen as evidence that the self is represented by a complex network of stimulus bindings. Thus, assessing processes which trigger self-prioritization is valuable for further understanding the generation of a self-representation or the self-concept in general.

Taken together, our results suggest a significant influence of salience on stimulus processing in the matching-task. Nevertheless, the results also indicate a prioritization of self-associated content independent of salience effects. Thus, in further research with the matching paradigm, the salience influence should be kept in mind. Taken together, the assessment of the influence of salience on the prioritization of self-relevant pairings in the matching task revealed that the SPE is more than just the recoding of perceptually salient content – it reflects a genuine process of prioritization that is exclusive for self-relevant material.

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*About the composition of self-relevance:  
Conjunctions not features are bound to the  
self*

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# About the composition of self-relevance: Conjunctions not features are bound to the self

Sarah Schäfer<sup>1</sup> · Christian Frings<sup>1</sup> · Dirk Wentura<sup>2</sup>

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**Abstract** Sui and colleagues (*Journal of Experimental Psychology: Human Perception and Performance*, 38, 1105–1117, 2012) introduced a matching paradigm to investigate prioritized processing of instructed self-relevance. They arbitrarily assigned simple geometric shapes to the participant and two other persons. Subsequently, the task was to judge whether label-shape pairings matched or not. The authors found a remarkable self-prioritization effect, that is, for matching self-related trials verification was very fast and accurate in comparison to the non-matching conditions. We analyzed whether single features or feature conjunctions are tagged to the self. In particular, we assigned colored shapes to the labels and included partial-matching trials (i.e., trials in which only one feature matched the label, whereas the other feature did not match the label). If single features are tagged to the self, partial matches would result in interference, whereas they should elicit the same data pattern as non-matching trials if only feature conjunctions are tagged to the self. Our data suggest the latter; only feature conjunctions are tagged to the self and are processed in a prioritized manner. This result emphasizes the functionality of self-relevance as a selection mechanism.

**Keywords** Self · Selective attention · Binding · Feature conjunction

Multiple information simultaneously reach our brain in everyday life and appropriate selection is indispensable to

distinguish between significant and less significant information. A dimension to identify important information is self-relevance. Consequently, self-relevant content allocates attention automatically (Alexopoulos, Muller, Ric, & Marendaz, 2012) and is prioritized against non-self-relevant stimuli (Bargh, 1982; Gray, Ambady, & Lowent, 2004).

An important question concerns how stimuli become self-relevant. Recent evidence suggests that this process is much faster than previously assumed and that formerly neutral stimuli can be associated arbitrarily with the self after a simple instruction to do so (Sui, He, & Humphreys, 2012). In particular, Sui and colleagues introduced a paradigm in which participants learned associations of simple geometric forms with themselves, a familiar person, or a neutral instance. In a subsequent matching task, form-label pairings were presented and participants had to judge whether the pairings fitted to the previously learned associations. In several experiments, a prioritization of self-relevant trials was found in that correct self-relevant pairings were verified faster and more accurate than correct non-self-relevant pairings. This self-prioritization in the matching task has been replicated several times (Sui, Rotshtein, & Humphreys, 2013; Schäfer, Wentura, & Frings, 2015), its neuronal correlates have been investigated (Sui, Rotshtein, & Humphreys, 2013), and it has been extended from perception to action (Frings & Wentura, 2014).

The present paper is concerned with the cognitive representation of this new kind of instructed self-relevance. In all published experiments using the matching task, participants were instructed to tag an arbitrary shape (which was not shown but only instructed by a verbal description) to a particular label (the word “you”, “mother”, or “stranger”, for example). Then participants had to evaluate whether label-shape pairings matched the learned associations. For example, participants might have been instructed to tag a triangle to their self. After a few matching trials they knew how the particular

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triangle looked like (i.e., its color, specific shape, and size). Yet, are the single features of the triangle tagged to the self or is it the object in its specific feature configuration that becomes associated with the self?

Looking at the literature, both alternatives seem possible. On the one hand, one could presume that individual features of the matched stimulus are bound to the self. Such independent bindings between single features have been shown in the literature on stimulus-response binding. In particular, it has been argued that several features of one stimulus are connected to a response via separate binary bindings resulting in a number of binary bindings loosely connected and integrated in a so-called event file (Hommel & Colzato, 2004). Another important aspect of binding is that the perception of one of the integrated features induces the retrieval of the complete event file including the response (Hommel, 1998, 2004). Moreover, bindings might include perceptual as well as abstract information (Henson, Eckstein, Waszak, Frings, & Horner, 2014) and the mere planning of a response on a specific stimulus elicits a binding between the stimulus and the response, without executing the response (Wenke, Robert, & Nattkemper, 2007). By analogue, it can be hypothesized that after a few trials in the matching paradigm binary bindings between the features (color, shape, etc.) of the particular stimulus and the self have been generated. We will refer to this model as the *binary model*.

On the other hand, one might hypothesize that a holistic configuration of all features is bound to the self. This assumption can be backed up by findings from research on face processing, suggesting that the holistic composite of features is automatically extracted and effortlessly processed upon face presentation (Allison, Puce, Spencer, & McCarthy, 1999; cf. Rossion, 2014). Holistic processing can be found in more basic research as well: Using feature conjunctions in interference tasks suggests that only the complete repetition of the conjunction leads to interference (Khurana, Smith, & Baker, 2000, for evidence from a negative priming paradigm). Accordingly, one could presume that the complete feature conjunction of the matched stimulus is bound to the self. We will refer to this model as the *conjunction model*.

To distinguish between these possibilities, we modified the matching paradigm in that the self, a familiar person, and a neutral instance were associated with two particular features (color and shape). Participants learned, for example, the sentences “I am the red triangle. My mother is the blue circle. The chair is the green square.” In the subsequent matching task, pairings of the labels and colored shapes were shown which were either matching according to the learned associations (e.g., “I” with a red triangle), partially matching (e.g., “I” with a red square), or non-matching (e.g., “I” with a blue square).

Both models actually predict a benefit in matching trials compared with non-matching trials, because self-prioritization is expected in matching but not in non-matching trials. Moreover, the binary model suggests highest reaction times

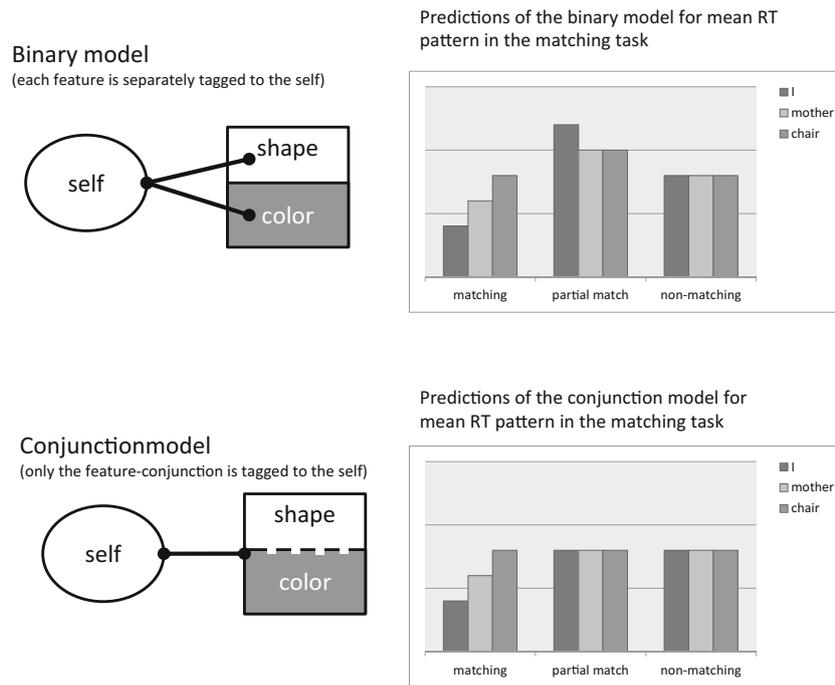
(RTs) in partial-matching trials, because one feature retrieves a matching label while the other feature retrieves a non-matching label. Dissolving this conflict will result in partial-matching costs, that is, increased RTs and/or error rates (comparable to stimulus-response binding where the perception of each feature introduces the retrieval of the corresponding response; Hommel, 2004). Above that, prioritized processing of self-related features will increase the conflict for self-relevant partial-matching trials, resulting in even higher costs in self-relevant partial matches (compared with non-self-relevant partial matches). In contrast, the conjunction model suggests that partial matches should elicit the same performance as non-matches, because only the complete configuration retrieves the corresponding label (Khurana, Smith, & Baker, 2000). Accordingly, response times should be comparable to those in non-matching trials. Figure 1 depicts the two competing models and the particular predictions.

## Method

**Participants** Sixty students from the University of Trier (43 females) took part in the experiment receiving course credit. Mean age was 23.5 (range 19-37) years, and all participants had normal or corrected-to-normal vision. Four participants were excluded, because they were outliers (i.e., far-out values according to Tukey, 1977) either according to the number of errors or the mean RT over all conditions, resulting in a sample size of 56 participants.

**Design** The experiment comprised a 3 (matching condition: *matching* vs. *partial matching* vs. *non-matching*)  $\times$  3 (label: *I* vs. *mother* vs. *chair*) within-participant design. The assignment of label and stimulus was balanced across participants following a Latin square.

With regard to power considerations, we focused on two effects. One difference between the two hypotheses concerns the main effect of matching condition (i.e., different RTs in matching, partial-, and non-matching trials due to different effects of the label within each matching condition). The other difference concerns the contrast between self-relevant and non-self-relevant partial-matching trials. Because an acceptance of the null hypothesis would be interpreted in favor of the conjunction model, we set  $\beta = \alpha = 0.05$ . The self-prioritization effect (as the difference between the mean RT in self-relevant matching trials and the mean RT in non-self-relevant matching trials) was rather large in previous studies ( $dz > 0.81$  in Sui et al., 2012). Thus, the assumption of  $dz = 0.50$  (i.e., a “medium” effect as defined by Cohen, 1988) for the effects described above seems to be quite conservative. To detect an effect of this magnitude with a probability of  $1 - \beta = 0.95$  and  $\alpha$ -value of 0.05, a sample size of 54 participants was required (G\*Power 3.1.3, Faul, Erdfelder, Lang, & Buchner, 2007).



**Fig. 1** Two models and the particular predicted outcomes. Note that the assumption of slightly decreased RTs for “mother”-matching trials compared to “chair”-matching trials is based on prior research (Sui et al., 2012)

**Material and apparatus** The experiment was conducted using standard PCs with TFT monitors that had display resolutions of 1680 x 1050 pixels, standard German QWERTZ keyboards, and E-Prime 2.0 software. Stimuli were the German words *Ich* [I], *Mutter* [mother], and *Stuhl* [chair] presented in white on black background. The geometric forms were square, circle, and triangle. Words were presented in Courier New, with a viewing distance of 60 cm resulting in a visual angle of approximately 0.57°. All stimuli were presented at the screen center, stimuli at a visual angle of 8.26° from the upper border of the screen, a fixation cross at 10.32°, and the label at 12.37°. The geometric forms were presented subtending each about 3.15° × 3.15° visual angle.

**Procedure** Participants were tested individually in sound-proof chambers. Task instructions were given on the screen and summarized by the experimenter. The experiment consisted of a learning phase and an experimental phase. In the learning phase, the three label-stimulus assignments (one assignment for each label) were shown on the display for 60 seconds. For a particular participant this instruction might read: “I am the red triangle. My mother is the green square. The chair is the blue circle.” Participants were instructed to place the index finger of the left hand on the S-key (non-matching response) and the index finger of the right hand on the L-key (matching response).

In the experimental phase, each trial started with a 500-ms presentation of a black screen, followed by a fixation cross for 500 ms, the label-stimulus assignment for 100 ms, and

another black screen until the participant responded or 1500 ms had elapsed. Participants’ task was to judge whether the displayed label-stimulus pairing corresponded to the initially learned assignment or not. They were explicitly instructed that only assignments with the correct stimulus and the correct color should be classified as matching assignments. Assignments with only one correct feature, that is, when either the color or the shape of the stimulus corresponds to the learned assignment, should be classified as non-matching assignments.

One experimental session consisted of a practice block with 36 trials and an experimental block with 216 trials. In the experimental block, each label was presented in 72 trials, one third with matching assignments, one third with partial-matching assignments (to be classified as non-matching assignments), and one third with non-matching assignments. The same proportions were realized in the practice trials. Trials were presented in random order.

## Results

Only correct responses with RTs above 100 ms and below 3 interquartile ranges above the third quartile of the overall RT distribution (far-out values according to Tukey, 1977) were used for the RT analysis. Averaged across participants, 92.2 % of the trials were selected for RT analysis; 7.1 % of the trials were excluded because of erroneous responses and

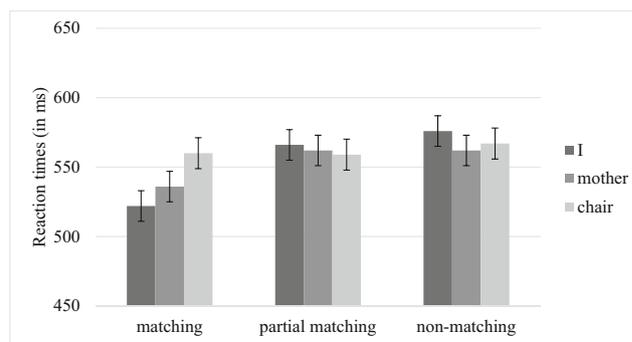
**Table 1** Mean RTs (in milliseconds) and error rates (in %) as a function of matching condition (*matching* vs. *partial matching* vs. *non-matching*) and label (*I* vs. *mother* vs. *chair*). Standard deviations in brackets

Matching condition	Label	RTs	Error rates
<i>Matching</i>	<i>I</i>	522 (73)	10.5 (10.6)
	<i>mother</i>	536 (94)	10.7 (9.4)
	<i>chair</i>	560 (82)	13.5 (9.7)
<i>Partial matching</i>	<i>I</i>	566 (79)	5.7 (6.8)
	<i>mother</i>	562 (84)	5.4 (6.6)
	<i>chair</i>	559 (84)	3.7 (4.6)
<i>Non-matching</i>	<i>I</i>	576 (71)	5.4 (6.3)
	<i>mother</i>	562 (79)	3.9 (5.9)
	<i>chair</i>	567 (85)	5.0 (5.9)

0.7 % due to the RT outlier criteria. Mean RTs and error rates are shown in Table 1.

**Reaction times** In a 3 (matching condition: *matching* vs. *partial matching* vs. *non-matching*)  $\times$  3 (label: *I* vs. *mother* vs. *chair*) repeated-measures MANOVA (see O'Brien & Kaiser, 1985, for the use of MANOVA analyzing repeated - measures designs) with mean RTs as the dependent variable, the main effect of label missed the conventional criterion of significance,  $F(2,54) = 2.87, p = .065, \eta_p^2 = 0.10$ , whereas the main effect of matching condition was significant (we will consider this effect below). We expected the interaction of label and matching condition to be significant; this was indeed the case with  $F(4,52) = 5.34, p = 0.001, \eta_p^2 = 0.29$ , indicating that the effect of the label differs according to the matching condition. Following this interaction and according to Sui et al. (2012), each matching condition was analyzed separately. In the matching condition, a one-factorial MANOVA with the within-participant factor label revealed a significant main effect of the label,  $F(2,54) = 8.73, p = 0.001, \eta_p^2 = 0.24$ ; that is, mean RTs varied significantly in dependence of the label. Helmert contrasts revealed a self-prioritization effect, indicating faster RTs in self-relevant matching trials (with the label “I”) compared with the average mean RT in non-self-relevant matching trials (with the label “mother” or the label “chair”),  $F(1,55) = 9.29, p = 0.004, \eta_p^2 = 0.15$ . The second Helmert contrast (“mother” vs. “chair”) was significant as well,  $F(1, 55) = 8.64, p = 0.005, \eta_p^2 = 0.14$ , RTs in matching trials with the label “mother” were faster than matching trials with the label “chair” (Fig. 2).<sup>1</sup> Comparable to Sui and colleagues’

<sup>1</sup> In fact, a follow-up test comparing RTs in self-relevant matching trials with RTs in matching trials with the label “mother” missed the conventional criterion of significance,  $t(55) = 1.50, p = .07$  (one-tailed). Given prior research using this paradigm (e.g., Sui et al., 2012), however, it is within the range of expectations that “mother” shows a prioritization effect compared to neutral labels, though extenuated with regard to the self.

**Fig. 2** Mean RTs as a function of label and matching condition. Error bars depict confidence intervals (95 %) for a repeated-measures design according to Jarmasz & Hollands, 2009

findings, in the non-matching trials, the label did not affect performance at all,  $F(2,54) = 2.43, p = 0.097, \eta_p^2 = 0.08$ . In the partial-matching condition, a one-factorial MANOVA with the within-participant factor label yielded a non-significant main effect,  $F < 1$ , indicating that even in partial-matching trials mean RTs did not vary in dependence of the label.

More relevant for testing the predictions of the binary versus conjunction model was the significant main effect of matching condition in the 3  $\times$  3 MANOVA,  $F(2,54) = 13.24, p < 0.001, \eta_p^2 = 0.33$ , indicating that RTs differed according to the matching of the label-stimulus pairing (averaged across all labels). Simple contrasts revealed significantly faster mean RTs in matching trials compared to mean RTs in partial-matching trials,  $F(1,55) = 15.31, p < 0.001, \eta_p^2 = 0.22$ , but no significant difference between mean RTs in partial- and non-matching trials,  $F(1,55) = 2.08, p = 0.155$ . That is, participants responded faster in matching trials than in partial- and non-matching trials, but partial- and non-matching trials did not differ significantly (Fig. 2). Thus, no partial-matching costs emerged.

To test our second prediction of the binary model, we checked whether partial-matching costs in self-relevant trials were covered by certain effects in non-self-relevant trials. A one-factorial MANOVA on self-relevant trials with the within-participant factor matching condition revealed a significant main effect,  $F(2,54) = 30.48, p < 0.001, \eta_p^2 = 0.53$ , yet a comparison of partial-matching and non-matching trials showed that participants did not respond more slowly in partial-matching trials (actually, they responded even faster in partial-matching trials,  $F(1, 55) = 4.54, p = 0.038, \eta_p^2 = 0.08$ ).

**Error rates** A 3 (matching condition: *matching* vs. *partial matching* vs. *non-matching*)  $\times$  3 (label: *I* vs. *mother* vs. *chair*) repeated-measures MANOVA with error rates revealed no significant main effect of label,  $F < 1$ , but a significant main effect of matching condition,  $F(2,54) = 28.98, p < 0.001, \eta_p^2 = 0.52$ , and a significant interaction of both,  $F(4,52) = 4.14, p = 0.006, \eta_p^2 = 0.24$ .

The interaction indicated a modulation of the effect of the label due to the matching condition. Thus, one-factorial MANOVAs with the within-participant factor label in each matching condition were computed but revealed no significant effects. In matching trials, neither the main effect of label,  $F(2, 54) = 2.22, p = 0.119$ , nor the Helmert contrast, indicating the difference between self- and non-self-relevant trials,  $F(1, 55) = 1.76, p = 0.191$ , was significant. Furthermore, neither in partial-matching ( $F(2, 54) = 3.11, p = 0.053$ , for the main effect,  $F(1, 55) = 2.03, p = 0.160$ , for the Helmert contrast) nor in non-matching trials ( $F(2, 54) = 1.52, p = 0.227$ , for the main effect,  $F(1, 55) = 1.62, p = 0.208$ , for the Helmert contrast) the label affected error rates significantly.

The main effect of matching condition in the  $3 \times 3$  MANOVA showed that error rates differed according to the matching of the label-stimulus pairing. Simple contrasts revealed a significant difference between error rates in matching and partial-matching trials,  $F(1, 55) = 48.90, p < 0.001, \eta_p^2 = 0.47$ , but no significant difference between error rates in partial- and non-matching trials,  $F < 1$ . That is, participants made more errors in matching trials but did not make more errors in partial-matching than in non-matching trials, indicating no partial-matching costs in error rates.

A one-factorial MANOVA on self-relevant trials with the within-participant factor matching condition showed a significant main effect,  $F(2, 54) = 6.51, p = 0.003, \eta_p^2 = 0.19$ , but simple contrast comparing partial- and non-matching trials indicated that participants did not make more errors in partial-matching trials,  $F < 1$ .

## Discussion

We replicated the self-prioritization effect in that RTs were significantly faster for verifications of self-relevant matching trials than for verifications of non-self-relevant matching trials. Second, we replicated that this pattern of means was exclusively for the matching trials, that is, in the non-matching trials no effect of label was observed. These parts of the data pattern are in line with all the published evidence from the matching paradigm (Sui et al., 2012).

Most importantly for our research question was the performance in partial-matching trials, in detail, whether partial repetitions of self-associated features result in interference or not. In fact, the observed data pattern was in line with the conjunction model in all aspects. In particular, RTs in matching trials were faster compared to RTs in non-matching trials, due to a self-prioritization effect working only in matching trials. In addition, partial matches did not result in interference (regardless of the particular label) and performance was comparable to non-matches. Furthermore, the different label conditions were comparable within the partial-matching trials; hence, the self-relevant label did not affect performance in partial

matches. As a consequence, the binary model cannot explain the observed data pattern. The cognitive representation of instructed self-relevance comprises feature conjunctions.

Our argument in deciding whether instructed self-relevance is holistic or binary was whether single features or conjunctions are tagged to the self. One might argue that we have played it unfair. In actual fact, we instructed conjunctions (“You are the red triangle.”) and we reinforced conjunctions (only if both features matched, a matching response had to be given). However, binding models would still predict partial-matching costs, because the idea would be that one particular feature (say the shape) becomes bound to another particular feature (say the matching label); accordingly in partial-matching trials the two stimulus features each retrieve possibly different labels (e.g., the shape might be tagged to the label “mother” while the color might be tagged to the label “I”) thereby causing interference, which should lead to higher RTs. This was not the case in our data.

Note that, according to visual attention theories, stimulus conjunctions (i.e., objects) are supposed to be processed at a quite late stage of processing, whereas single features are processed in a preattentive stage (Treisman & Gelade, 1980; Wolfe, 1994). Our results indicate that the SPE occurs at rather late stages of visual processing. Hence, one implication would be that the number of features tagged to the self is irrelevant, because only the whole object is associated with the self and profits from prioritization.

Whereas in previous studies dealing with self-relevant content the self-relevant material (e.g., participant’s own name, autobiographical information) was highly overlearned, this confound is eliminated in the matching paradigm. Consequently, the results gathered with the matching paradigm in general speak in favor of the attention allocating potential of self-relevant information independent of the learning history. Our results suggest as well how easily self-relevance can be acquired. Most importantly, it suggests that objects comprising several features immediately acquire the status of a self-relevant item. The assumption of a fast and general tendency to tag complex contents to the self, whenever it appears to be appropriate, is sustained by the variety of stimuli that can be used in the matching task. The prioritization of self-related pairings after the assignment of movements with the self (Frings & Wentura, 2014) indicates the SPE’s independence of the associated stimulus material. Above that, not only associations with the label “I” but even with other self-related stimuli reveal prioritization. That was shown by a study in which four geometric forms were associated with four badges either of a favorite, a rival, or two neutral football teams, and later responses to favorite-associated pairings were faster and more accurate than responses to rival-associated pairings (Moradi, Sui, Hewstone, & Humphreys, 2015).

The observed effects in the matching paradigm use direct instructions to create self-relevance and a task in which

participants are required to evaluate these instructions (as a result the instruction is task-relevant). It is clear that self-relevance in real life is usually not acquired this way. So one challenge for research with the matching task will be to analyze the relationship of instructed self-relevance with previous research on self-relevance. In this regard, one might link instructed self-prioritization to research on self-relevance and extension of the self. Recent research on the mere ownership effect in memory (Cunningham, Turk, Macdonald, & Macrae, 2008) shows that objects (i.e., meaningful feature configurations) that are randomly assigned to the self are better remembered than objects assigned to someone else. This effect seems to be a mere effect of extending the self to objects (Kim & Johnson, 2010, for neurocognitive evidence). Thus, the self-prioritization of feature conjunctions (i.e., objects) resembles the mere ownership effect and complements research on the extended self in general and supports the pivotal role of the me/mine—not me/not mine border in our psychic life (Belk, 1988).

Self-prioritization is characterized by an automatic attention allocation through self-relevant stimuli and therefore allows for fast processing of highly relevant information in everyday life. However, such prioritized processing of information appears useful only if the boundaries of self-relevance are fairly strict, as loose boundaries would possibly increase the number of potentially relevant stimuli and false alarm rates, thereby invalidating the function of self-relevance as a selection mechanism. Thus, prioritization of stimuli that share only simple features with a self-relevant stimulus would reduce our sensitivity for important information and redirect our attention to potentially less important information. Summarized, it is very adaptive and functional that self-prioritization affects only conjunctions and is unaffected by partial matches.

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# Self-Prioritization Beyond Perception

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**Abstract.** Recently, Sui, He, and Humphreys (2012) introduced a new paradigm to measure perceptual self-prioritization processes. It seems that arbitrarily tagging shapes to self-relevant words (I, my, me, and so on) leads to speeded verification times when matching self-relevant word shape pairings (e.g., me – triangle) as compared to non-self-relevant word shape pairings (e.g., stranger – circle). In order to analyze the level at which self-prioritization takes place we analyzed whether the self-prioritization effect is due to a tagging of the self-relevant label and the particular associated shape or due to a tagging of the self with an abstract concept. In two experiments participants showed standard self-prioritization effects with varying stimulus features or different exemplars of a particular stimulus-category suggesting that self-prioritization also works at a conceptual level.

**Keywords:** self-prioritization, feature variance, conceptual processing

A function of self-relevance is that it guides our attention and behavior as self-relevant stimuli indicate important sensory inputs for our cognitive system. Accordingly, modulations of attentional processing due to self-relevance have been shown in different paradigms of selective attention (e.g., Alexopoulos, Muller, Ric, & Marendaz, 2012; Bargh, 1982; Giesbrecht, Sy, & Lewis, 2009; Shapiro, Caldwell, & Sorensen, 1997). Moreover, self-relevant stimuli are detected more easily and are harder to ignore as compared to non-self-relevant ones (Frings, 2006).

Typically, these effects are interpreted as reflecting a “learning history” that has been taken place outside experimental sessions; for example, using one’s own name as the stimulus in the self-relevant condition of an experiment implies that one’s own name has been heard and used by others so often when referring to one’s own self that the name has become *self-relevant* in due course. Currently, a new paradigm was investigated to assess these self-prioritization effects more closely (Sui, He, & Humphreys, 2012). Thereby, even after a very short and completely arbitrary tagging of neutral geometric shapes with the self, self-prioritization processes have been reported. By associating formerly neutral material with the self not only previous problems with confounding factors were eluded (material used in the self-relevant condition was highly overlearned and more familiar than the material used in the other-relevant condition) but also the generation of self-relevance can be assessed. In particular, Sui and colleagues combined geometric shapes either with the participant or with one of two other persons (e.g., a circle was paired with the participant, a square was paired with the participant’s best friend, and a triangle was paired with a stranger). Subsequently different name shape assignments were shown on the display and the participant had to judge whether the particularly

shown assignment matches a learned assignment or not. Reaction times and the signal detection-index  $d'$  showed a self-prioritization effect in that verifications for matching self-related assignments were faster and more accurate than verifications for matching assignments with a familiar or a strange person (Sui et al., 2012). In follow-up experiments, Sui, Sun, Peng, and Humphreys (2014) replicated this effect and found evidence that the proportion of self-relevant and non-self-relevant trials did not influence the self-prioritization effect – suggesting that the effect is not strategic in nature.

So far, the self-prioritization effect in this paradigm has been interpreted in terms of perceptual processes. For example, the effect was shown to be independent of word length, frequency, and concreteness. Note further that in all previous experiments on the self-prioritization effect, the instructions might have been encoded at the conceptual level (because the actual stimuli were typically not shown in the instruction phase) while after the practice trials it should have been clear which particular stimulus fits to which particular shape. As a result, the observed effect of self-prioritization in the experimental trials might indeed reflect a modulation of perceptual processing. Furthermore, the interaction of visual degradation with the self-prioritization effect (greater self-prioritization under low contrast conditions) indicated its occurrence at early processing stages (Sui et al., 2012). Following this interpretation, one could assume that the self-prioritization effect denotes a perceptual preference of specific stimuli after they had been associated with the self. Beyond that, the effect could be extended from visual processing to action. Comparable to the original study, simple movement directions (i.e., up, down, left, right) were assigned to the participant’s self, to the mother, to a stranger, or to a neutral

label. In the following trials, participants executed a movement (triggered by a cue) which was followed by a label and they had to judge whether the particular label-movement pairing matched or not. A self-prioritization effect occurred, indicated by faster and more accurate responses to self-relevant movement-label pairings (Frings & Wentura, 2014). Note, however, participants learned associations of labels and movement directions without knowing at learning which particular type of movement they would have to execute later on (i.e., they learned just the movement direction). The same can be said for the original study of Sui and colleagues (2012), as participants were not informed about the particular appearance of the shape that had to be matched to the self. Hence, it is well possible that participants encoded shapes (in the experiments by Sui et al.) and movements (in the study of Frings and Wentura) at a conceptual level and tagged an abstract concept to the self or to the other instances. Thus, the question arises if the given effect is due to a perceptual preference of specific stimuli, that is, if self-prioritization only affects perceptual processing, or if it also takes place at a conceptual level.

The following experiments were conducted to address this question. In the first experiment geometric shapes were associated to the self or neutral others in the learning phase but in the subsequent matching task shapes with varying features (i.e., color, orientation, hatching) were presented, hindering the tagging of the labels with a specific stimulus percept. The self-prioritization effect for the shapes with varying features was measured and compared to the effect in a condition with constant features. In a second experiment complex concepts (i.e., musical instruments) were associated with the self or neutral others and in the matching task different exemplar stimuli (from two modalities; i.e., visual and auditory) were presented. If abstract concepts rather than specific stimuli are tagged to the self then the self-prioritization effect should emerge irrespective of feature variation or different exemplars of the stimulus-category.

## Experiment 1

In the first experiment we manipulated whether features of the shapes in the matching task were constant or varying. In one condition participants learned associations between the labels and specific geometric shapes with constant shape features. In detail, a square, a triangle, and a circle were associated with the participant's self, one familiar person, or a neutral instance. Here, the shapes always had the same appearance. In a second condition participants learned associations between the labels and geometric shapes with varying features. For example, a given participant might learn the association of the label "I" with the triangle, yet in the experimental trials the features of the triangle varied. Thus, the two experimental conditions differed in that the percept of the features varied in one condition but was constant in the other condition. If self-prioritization can be

independent of the specific percept of the shapes, the self-prioritization effect should not differ between the two conditions.

## Method

### Participants

Sixty students from the University of Trier (50 female) took part in the experiment receiving course credit for participation. Mean age was 21.5 years (ranging from 19 to 33 years) and all participants had normal or corrected-to-normal vision.

### Design

The experiment comprised a 2 (shape feature condition: *varying* vs. *constant*)  $\times$  3 (label: *I* vs. *mother* vs. *chair*)  $\times$  2 (matching condition: *matching* vs. *non-matching*) design. The factor shape feature condition was varied between participants whereas the two other factors were varied within participants. The assignment of label and shape was balanced across participants following a Latin square.

With regard to power considerations, we focused on two effects: (1) We wanted to replicate the self-prioritization effect in both shape feature condition. The self-prioritization effect itself (as the difference between the mean reaction time in self-relevant matching trials and the mean reaction time in non-self-relevant matching trials) was rather large in previous studies ( $d_z > 0.81$  in Sui et al., 2012). Thus, the assumption of  $d_z = 0.50$  (i.e., a "medium" effect as defined by Cohen, 1988) for the yet unexplored self-prioritization effect with varying features seems to be quite conservative. To detect an effect of this magnitude with a probability of  $1 - \beta = .80$  and an  $\alpha$ -value of .05 (one-tailed), a sample size of 27 participants was required; actual power with  $N = 30$  was  $1 - \beta = .85$ . (2) If it should turn out that there is no self-prioritization effect with varying features, this null effect should be accompanied by a significant difference in self-prioritization between the conditions of constant and varying features. Given  $N = 60$  and an  $\alpha$ -value of .05 (one-tailed), an effect of  $d = 0.65$  can be detected with  $1 - \beta = .80$ . Since we expect a large effect for the constant condition (see above), this effect size for the difference to a null effect is plausible. Calculations were done using GPower 3.1.3 (Faul, Erdfelder, Lang, & Buchner, 2007).

### Material and Apparatus

The experiment was conducted using standard PCs with TFT monitors that had a display resolution of  $1,280 \times 1,024$  pixels, and standard German QWERTZ keyboards. The experiment was run by the E-Prime 2.0 software (Psychology Software Tools, Inc., Sharpsburg, PA). Stimuli were the German word "Ich" [I] as a self-relevant

stimulus, the German word “Mutter” [mother] as a familiar stimulus, and the German word “Stuhl” [chair] as a neutral stimulus. Words were presented in white on black background. The geometric shapes were square, triangle, and circle in the condition with constant shape features and square, triangle, and rectangle in the condition with varying shape features.<sup>1</sup> Words were presented in Courier New with a viewing distance of 60 cm, resulting in a visual angle of about 0.5°. Viewing distance was controlled by a chin rest on which the participant had to lay down his chin. All stimuli were presented at the screen center, the shape at a visual angle of 11.0° from the upper border of the screen, a fixation cross at 13.8°, and the label at 16.6°. The triangle was presented subtending 3.4° × 3.4° visual angle, the rectangle 3.5° × 1.6°, and the square 2.2° × 2.2°. In the condition with varying shape features, color (yellow, green, red, blue), orientation (straight, oblique), and hatching (horizontal, vertical, diagonal up, diagonal down) were also varied (see Appendix A).

## Procedure

The participants were tested individually in soundproof chambers. Task instructions, such as that the participant had to learn particular label-shape assignments, were given on the screen and summarized by the experimenter. Closely following the procedure of Sui et al. (2012), the experiment consisted of two phases. First, label-shape assignments were shown on the display for 60 s. For a particular participant this instruction might read: “I am a triangle. My mother is a square. The chair is a rectangle.” Participants were instructed to remember their assignment and were told that they had to evaluate label-shape pairs with respect to this assignment in the second phase of the experiment. Participants were then instructed to place the index finger of the left hand on the S-key (non-matching response) and the index finger of the right hand on the L-key (matching response).

In each trial of the second phase of the experiment, after a 500 ms presentation of a black slide, a fixation cross appeared for 500 ms followed by one label-shape assignment for 100 ms and again a black slide until the participant responded or 1,500 ms had elapsed (see Figure 1).

Participants' task was to judge whether the displayed label-shape assignment corresponded to the initially learned assignment or not. Half of the participants were assigned to the condition with varying shape features, in which 96 different shape versions were used. One experimental session consisted of a practice block with 12 practice trials and an experimental block with 192 trials. Each label was presented in 64 trials, half of them with matching assignments and half of them with non-matching assignments. Note that in non-matching assignments the labels were combined with one of the two other (not associated) shapes, for example the label “mother” was presented with the self-associated shape. Consequently, a clear separation of

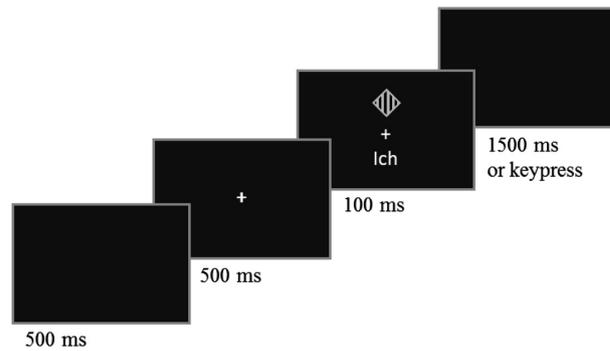


Figure 1. Example of a self-relevant trial in the condition with varying shape features with the German word “Ich” [I] as the label.

self-, mother-, or chair-relevance is possible in matching trials but not in non-matching trials. The same proportions of trials as in the experimental phase were realized in the practice phase. Trials were presented in random order.

Half of the participants were assigned to the condition with constant shape features. In this condition, exactly the same matching task was applied with the following slight changes. Shapes were always white, had a straight orientation, and never had a hatching. The used shapes were a square, a triangle, and a circle (i.e., the shapes used by Sui et al., 2012). In both conditions the geometric shapes were presented on a black display and participants executed 180 experimental trials.

## Results

Only correct responses with reaction times (RTs) above 100 ms and below three interquartile ranges above the third quartile of the overall RT distribution (Tukey, 1977) were used for the RT analysis. Averaged across participants, 83% of the trials were selected for the RT analysis. Trials (12.8%) were excluded because of erroneous responses and 4.1% due to the RT outlier criteria. All effects referred to as statistically significant throughout the text are associated with  $p$ -values less than .05, two-tailed unless otherwise noted. Mean RTs and error rates of both shape feature conditions are shown in Table 1.

## Reaction Times

RTs were submitted to a 2 (shape feature condition: varying vs. constant) × 3 (label: I vs. mother vs. chair) × 2 (matching condition: matching vs. non-matching) repeated-measures MANOVA. All main effects were significant,  $F(2, 57) = 35.81$ ,  $p < .001$ ,  $\eta_p^2 = .58$ , for label,  $F(1, 58) = 178.30$ ,  $p < .001$ ,  $\eta_p^2 = .76$ , for matching

<sup>1</sup> To use squares, triangles, and circles is the standard established by Sui et al. (2012). We had to replace the circle by a rectangle for the condition with varying features so as to manipulate the orientation.

Table 1. Mean reaction times (in ms) and error rates (in %) as a function of matching condition, label, and shape feature condition. Standard deviations in brackets.

Matching condition	Label	Varying shape features		Constant shape features	
		RTs	Error rates	RTs	Error rates
Matching	I	634 (105)	10.7 (13.8)	586 (100)	5.1 (4.9)
	Mother	697 (113)	14.1 (11.2)	634 (91)	7.9 (6.6)
	Chair	772 (137)	29.3 (21.7)	667 (98)	12.2 (8.4)
Non-matching	I	777 (113)	10.6 (13.8)	722 (83)	8.2 (7.1)
	mother	774 (101)	18.4 (14.0)	715 (80)	8.7 (6.4)
	Chair	792 (96)	20.0 (11.8)	740 (88)	9.1 (10.0)

condition, and  $F(1, 58) = 8.48$ ,  $p = .005$ ,  $\eta_p^2 = .13$ , for shape feature condition, indicating that RTs differ for the labels, are shorter in matching than in non-matching trials, and are shorter in the constant shape feature condition than in the varying shape feature condition. The interaction of label and matching condition was also significant,  $F(2, 57) = 23.36$ ,  $p < .001$ ,  $\eta_p^2 = .45$ , revealing different effects of the label in matching than in non-matching trials. The three-way interaction of shape feature condition  $\times$  label  $\times$  matching condition was not significant,  $F(2, 57) = 2.73$ ,  $p = .074$ ,  $\eta_p^2 = .09$ , suggesting that feature variance did not influence the self-prioritization process. No further interaction effects were significant, all  $F$ s  $< 1.65$ , all  $p$ s  $> .20$ .

In accordance with Sui et al. (2012) and due to the fact that a separation between self- and other-relevant trials can only be made in matching trials, the self-prioritization effect was assessed in the matching trials. Particularly, it was computed as the difference between performance in self-relevant (i.e., “I”) matching trials and performance in non-self-relevant matching trials (i.e., “mother” and “chair”), which corresponds to the first Helmert contrast in the repeated-measures MANOVA. For both shape feature conditions, the Helmert contrast between the mean RT in self-relevant matching trials and the average RT in non-self-relevant matching trials was significant,  $F(1, 29) = 31.01$ ,  $p < .001$ ,  $\eta_p^2 = .52$  for the condition with varying features and  $F(1, 29) = 13.24$ ,  $p < .001$ ,  $\eta_p^2 = .31$  for the condition with constant features (see Figure 2a), showing shorter RTs in matching trials with the self-relevant label.<sup>2</sup> Moreover, the self-prioritization effects did not differ significantly between the shape feature conditions,  $F(1, 58) = 1.97$ ,  $p = .166$ ,  $\eta_p^2 = .03$ . No comparable effect was found in non-matching trials in either of the conditions, both  $F < 1$ , indicating that the label did not affect RTs in non-matching trials.

### Accuracy Rates and Signal Detection Indices

Accuracy rates were analyzed using signal detection sensitivity indices for each label condition, following the logic suggested by Sui and colleagues (2012). Correct responses in matching trials were considered hits while erroneous responses were considered missings. In non-matching trials, correct responses were considered correct rejections and erroneous responses were considered false alarms. Note that for  $n = 15$  participants  $d'$  could not be calculated since these participants had a false alarm rate of zero. To account for this, we followed the so-called log-linear approach (see Hautus, 1995; Stanislaw & Todorov, 1999) which involves adding 0.5 to the number of hits and the number of false alarms and adding one to the number of signal trials (i.e., matching trials) and the number of noise trials (i.e., non-matching trials).

The resulting  $d'$  indices in each shape condition and for both shape feature conditions were submitted to a 2 (shape feature condition: varying vs. constant)  $\times$  3 (shape: self- vs. mother- vs. chair-associated) MANOVA. The main effect of shape and the main effect of shape feature condition were significant,  $F(2, 57) = 12.27$ ,  $p < .001$ ,  $\eta_p^2 = .30$ , and  $F(1, 58) = 27.41$ ,  $p < .001$ ,  $\eta_p^2 = .32$ , suggesting that sensitivity differs for the shapes and is higher in the constant than in the varying shape feature condition. The interaction was not significant,  $F < 1$ .

The self-prioritization effect was computed as the difference between mean  $d'$  in self-relevant trials and mean  $d'$  in non-self-relevant trials (see Figure 2B). Note again that this difference corresponds to the first Helmert contrast in the repeated-measures MANOVA. In both shape feature conditions this contrast was significant,  $F(1, 29) = 3.04$ ,  $p = .046$  (one-tailed),<sup>3</sup>  $\eta_p^2 = .10$  for varying shape features and  $F(1, 29) = 3.78$ ,  $p = .031$  (one-tailed),  $\eta_p^2 = .12$  for

<sup>2</sup> A comparison of mean RTs in the self-relevant condition and mean RTs in the second fastest condition, the mother condition, revealed significant differences as well, for varying and for constant shape features,  $F(1, 29) = 6.52$ ,  $p = .016$ ,  $\eta_p^2 = .18$ , and  $F(1, 29) = 6.00$ ,  $p = .021$ ,  $\eta_p^2 = .17$ , respectively.

<sup>3</sup> Methodologically, an  $F$ -test with  $df = 1$  corresponds to a  $t$ -test. Thus, given our specific predictions, a one-tailed test is allowed (see Maxwell & Delaney, 1990, p. 144).

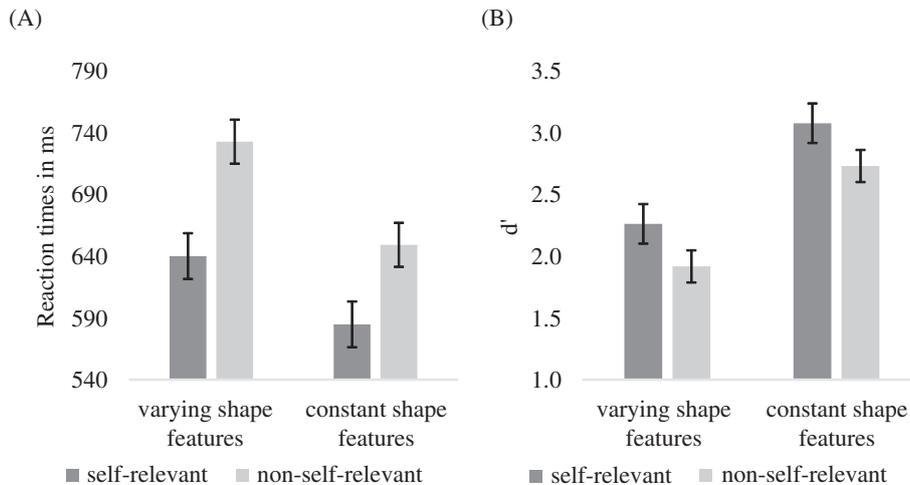


Figure 2. (A) Mean RTs in self-relevant and non-self-relevant matching trials, separately for varying and constant shape features. Error bars depict standard error of the mean. (B)  $d'$  in self-relevant and non-self-relevant matching trials, separately for varying and constant shape features. Error bars depict standard error of the mean.

constant shape features, suggesting higher sensitivity in trials with a self-associated shape independent of the shape feature condition. As with RTs, even in  $d'$  the self-prioritization effects did not differ significantly between the shape feature conditions,  $F < 1$ .

## Discussion

We replicated the self-prioritization effect of Sui and colleagues (2012) in the conditions with constant features as well as in a condition with varying shape features. In fact, the self-prioritization effect did not differ between both of these conditions. Thus, the feature variance manipulation did not exert an influence on self-prioritization suggesting that the effect has its source at a conceptual level.

Note, that we did observe one difference between the conditions, precisely a main effect of shape feature, condition, implying shorter reaction times and higher sensitivity rates with constant shape features. This main effect suggests that the feature variance manipulation affected perception, corresponding to the Garner interference, as variance of an irrelevant dimension impedes processing of the relevant dimension (Garner & Felfoldy, 1970).

The self-prioritization effect in terms of reaction time as well as in terms of sensitivity seems to be independent of the combined presentation of the self-relevant label with one specific stimulus. As a result, it can be concluded that participants do not tag a particular shape to the self but probably a concept: if a person tags, for example, a triangle to the self, then prioritized processing generalizes to different types of triangles. Though, even with varying shape features the 32 stimuli in the self-relevant condition share one feature by definition, namely their shape. Hence, one might argue that the tagging of the shape and the label is just binary, that is, only the shape (irrespective of its color, orientation, and hatching) is tagged to the self as the shape itself was constant even in the condition with varying shape features. To rule out this possibility we conducted Experiment 2.

## Experiment 2

In Experiment 2 three labels (including one self-relevant and two other-relevant labels) were associated with concepts and in the following matching task, 16 different visual or auditory exemplars of each concept were presented. In detail, the participant's self, the mother, and a friend were associated with a piano, a flute, or a guitar (e.g., "I am a piano. My mother is a flute. A friend is a guitar."). Subsequently, assignments of one label and one exemplar of any of the three stimulus categories, that is, either a tone or a picture of one instrument, were presented on the screen, the participant being instructed to decide whether it matches the learned assignments or not. If self-prioritization refers to the abstract concept then the self-prioritization effect should still be found when the label is paired with different exemplars of the self-assigned category.

## Method

### Participants

Thirty students from the University of Trier (19 female) took part in the experiment receiving course credit. None of them had participated in Experiment 1. Mean age was 22.1 years (ranging from 19 to 28 years) and all participants had normal or corrected-to-normal vision. Again, the assumption of  $d_z = 0.50$  (i.e., a "medium" effect as defined by Cohen, 1988) for the self-prioritization effect with varying features is rather conservative (see Experiment 1). To detect an effect of this magnitude with a probability of  $1 - \beta = .80$  and an  $\alpha$ -value of .05 (one-tailed), a sample size of 27 participants was required; actual power with  $N = 30$  was  $1 - \beta = .85$  (Faul et al., 2007).

### Design

The experiment comprised a 2 (stimulus modality: *visual* vs. *auditory*)  $\times$  3 (label: *I* vs. *mother* vs. *friend*)  $\times$  2

Table 2. Mean reaction times (in ms) and error rates (in %) as a function of matching condition, label, and stimulus modality. Standard deviations in brackets.

Matching condition	Label	Visual stimulus		Auditory stimulus	
		RTs	Error rates	RTs	Error rates
Matching	I	471 (110)	3.4 (5.3)	449 (176)	11.5 (8.4)
	Mother	538 (141)	7.9 (8.0)	500 (173)	16.5 (11.3)
	Friend	554 (138)	14.5 (12.1)	549 (211)	19.2 (16.1)
Non-matching	I	585 (130)	7.5 (6.8)	524 (147)	9.7 (7.2)
	Mother	577 (123)	8.2 (6.9)	550 (161)	7.0 (7.0)
	Friend	591 (129)	6.2 (6.0)	576 (165)	11.4 (7.9)

(matching condition: *matching* vs. *non-matching*) design. All factors were varied within participants and the assignment of label and shape was balanced across participants following a Latin square.

## Material and Apparatus

The apparatus and stimuli were the same as in Experiment 1, except for the following details. First, stimuli were three human labels, in detail the German word “Ich” [I], the German word “Mutter” [mother], and the German word “Bekannter” [friend]. Second, the labels were associated with musical instruments, either with a flute, a piano, or a guitar. All stimuli were presented at the screen center, the label at a visual angle of 8.6° from the upper border of the screen, and a fixation cross at 14.3°. In half of the trials a picture of an instrument was presented for 200 ms at 19.9° from the upper border of the screen. The instruments were presented subtending 10.5° width with varying height. Each of the three instruments was represented by 16 different stimuli, that is, eight pictures and eight sounds. The pictures could be realistic or sketched, in color or in black and white, and in different orientations (for an overview of the used pictures see Appendix B). In the other half of the trials no picture was presented but a sound was played. Each instrument was represented by eight easily discriminable instrumental one tone-sounds. Each sound had an intensity of approximately 40 dB SPL, a length of 300 ms and was presented over headphones.<sup>4</sup>

## Procedure

Essentially, the procedure was the same as in Experiment 1, except that participants were instructed that in the following matching task instruments could be represented by pictures or sounds. Each trial of the matching task started with a 500 ms black slide followed by a fixation cross for 500 ms. Then the label was presented for 500 ms accompanied by the visual or auditory stimulus so that all stimuli had the same offset. Each trial ended with a black slide until

the participant responded or 1,500 ms had elapsed. Twenty-four practice trials and 240 experimental trials had to be executed.

## Results

Only correct responses with RTs above 100 ms and below three interquartile ranges above the third quartile of the overall RT distribution (Tukey, 1977) were used for the RT analysis. Averaged across participants, 88.9% of the trials were selected for RT analysis. Trials (10.2%) were excluded because of erroneous responses and 0.9% due to the RT outlier criteria. Mean RTs and error rates of both shape feature conditions are shown in Table 2.

## Reaction Times

RTs were submitted to a 2 (stimulus modality: visual vs. auditory)  $\times$  3 (label: I vs. mother vs. friend)  $\times$  2 (matching condition: matching vs. non-matching) repeated-measures MANOVA. All main effects were significant,  $F(2, 28) = 10.73$ ,  $p < .001$ ,  $\eta_p^2 = .43$ , for label,  $F(1, 29) = 69.80$ ,  $p < .001$ ,  $\eta_p^2 = .71$ , for matching condition, and  $F(1, 29) = 7.11$ ,  $p = .012$ ,  $\eta_p^2 = .20$ , for stimulus modality, indicating that RTs differ for the labels, are shorter in matching than in non-matching trials, and are shorter in the auditory stimulus condition than in the visual stimulus condition. Most important, the interaction of label and matching condition was also significant,  $F(2, 28) = 5.56$ ,  $p = .009$ ,  $\eta_p^2 = .28$ , revealing different effects of the label in matching than in non-matching trials. The three-way interaction of stimulus modality  $\times$  label  $\times$  matching condition was not significant,  $F(2, 28) = 1.26$ ,  $p = .300$ ,  $\eta_p^2 = .08$ , suggesting that the stimulus modality did not influence the self-prioritization process. No further interaction effects were significant, all  $F_s < 1.80$ , all  $p_s > .18$ .

Again the self-prioritization effect was computed as the difference between performance in self-relevant matching trials and non-self-relevant matching trials. For both

<sup>4</sup> We chose presentation time of sounds to be a bit longer than that of pictures because the meaning of sounds unfolds in the temporal dimension (in contrast to the spatially distributed information of pictures).

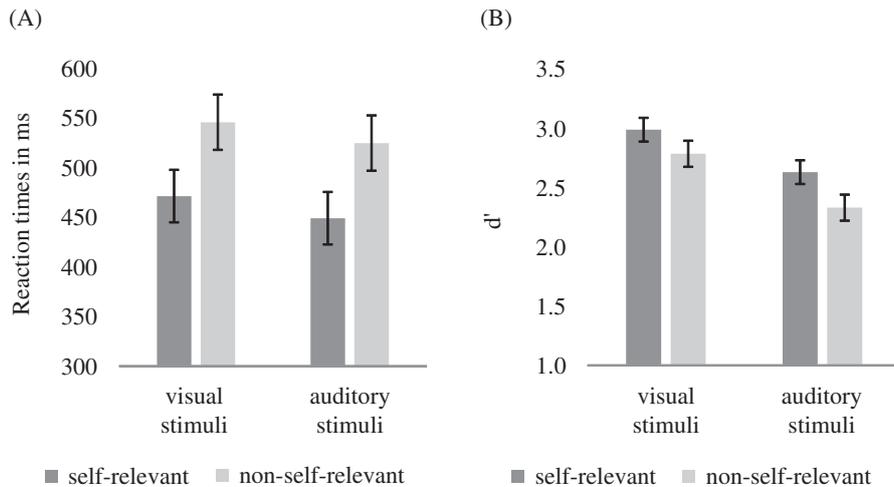


Figure 3. (A) Mean RTs in self-relevant and non-self-relevant matching trials, separately for visual and auditory stimuli. Error bars depict standard error of the mean. (B)  $d'$  in self-relevant and non-self-relevant matching trials, separately for visual and auditory stimuli. Error bars depict standard error of the mean.

stimulus modality conditions this particular Helmert contrast (see Experiment 1) was significant,  $F(1, 29) = 23.80$ ,  $p < .001$ ,  $\eta_p^2 = .45$ , for the condition with visual stimuli and  $F(1, 29) = 9.08$ ,  $p = .005$ ,  $\eta_p^2 = .24$ , for the condition with auditory stimuli (see Figure 3A), indicating that both with visual as well as with auditory stimuli reactions were faster for self-relevant matching trials.<sup>5</sup> Additionally, the self-prioritization effects did not differ significantly between the stimulus modalities,  $F < 1$ .

In further analysis we looked into sequence effects (i.e., including stimulus modality repetition vs. changes as a factor). RTs were shorter in trials in which the stimulus modality repeated compared to trials in which the stimulus modality switched,  $F(1, 29) = 10.94$ ,  $p = .003$ ,  $\eta_p^2 = .27$ , for the main effect of stimulus modality switch. Still, the self-prioritization effect was not influenced by stimulus modality repetitions;  $F < 1$  for the interaction of stimulus modality repetition and the Helmert contrast indicating the self-prioritization effect.

### Accuracy Rates and Signal Detection Indices

Accuracy rates were analyzed using signal detection sensitivity indices for each shape condition, resulting in a sensitivity measure for self-associated shapes and non-self-associated shapes. As described for Experiment 1 we followed the log-linear approach (see Hautus, 1995; Stanislaw & Todorov, 1999).

The resulting  $d'$  indices in each shape condition and for both stimulus modality conditions were submitted to a 2 (stimulus modality condition: visual vs. auditory)  $\times$  3 (shape: self- vs. mother- vs. chair-associated) MANOVA. Both main effects were significant,  $F(2, 28) = 12.34$ ,  $p < .001$ ,  $\eta_p^2 = .47$ , for shape and  $F(1, 29) = 24.39$ ,  $p < .001$ ,  $\eta_p^2 = .46$ , for stimulus modality condition, indicating higher sensitivity in trials with a visual stimulus

and different sensitivity measures in dependence of the shape. The interaction was also significant,  $F(2, 28) = 3.41$ ,  $p = .047$ ,  $\eta_p^2 = .20$ , suggesting that the effect of the shape varied between the stimulus modality conditions.

For visual stimuli, the self-prioritization effect, indicated by the Helmert contrast of self-associated shapes compared to non-self-associated shapes, showed a significantly higher sensitivity for self-associated shapes,  $F(1, 29) = 5.96$ ,  $p = .021$ ,  $\eta_p^2 = .17$  (see Figure 3B). The Helmert contrast indicating the self-prioritization effect was significant for auditory stimuli, too,  $F(1, 29) = 7.45$ ,  $p = .011$ ,  $\eta_p^2 = .20$ . There was no significant difference between the self-prioritization effects in the two stimulus modality conditions,  $F < 1$ . This result indicates that the interaction of shape and modality reported above is due to the second contrast (i.e., mother vs. friend), which is of no further interest here.

Also  $d'$  indices of the self-prioritization effect were independent of stimulus modality repetitions. No main effect of stimulus modality repetition and no interaction with the Helmert contrast indicating the self-prioritization effect were measured, both  $F$ s  $< 1$ .

### Discussion

Again the self-prioritization effect was replicated. Moreover, RT data suggest an independence of the effect from the stimulus modality. Yet, the sensitivity indices indicate an interaction of the effect with the stimulus modality. Further analyses showed that the effect emerged in both conditions, that is, with visual and auditory stimuli and that self-prioritization was larger with auditory stimuli. Nevertheless, in Experiment 2 the self-prioritization effect emerged without the combination of the label and a specific stimulus. In contrast, labels and stimulus categories were instructed while different exemplars of these categories were presented in the matching trials. The effects

<sup>5</sup> Like in Experiment 1, a comparison of mean RTs in the self-relevant condition and mean RTs in the second fastest condition, the mother condition, revealed significant differences for both stimulus modalities,  $F(1, 29) = 12.71$ ,  $p = .001$ ,  $\eta_p^2 = .31$ , for visual stimuli, and  $F(1, 29) = 4.41$ ,  $p = .044$ ,  $\eta_p^2 = .13$ , for auditory stimuli.

independence of modality switch reinforces the association of a concept with the self. Furthermore, a binary tagging of the labels and one particular feature (as it could have been assumed in Experiment 1) was ruled out because the exemplars did not share one particular feature. In fact, self-prioritization of the self-relevant stimulus category was observed suggesting that this effect can occur beyond perceptual levels.

## General Discussion

Two experiments showed that the self-prioritization effect abstracts from a specific perceptual input, both from feature variance and from different stimulus exemplars. Therefore, the data support the hypothesis that the self-prioritization effect does not only trace back to a tagging of specific stimuli to the self-relevant label but to a tagging of semantic concepts to the self to which different perceptual objects can belong.

The self-prioritization effect was independent of feature variance (Experiment 1) and independent of the stimulus modality (Experiment 2), only the sensitivity indices in Experiment 2 indicated a larger effect with auditory stimuli. Regardless of our research question here, this ordinal interaction could be a hint for further research to examine the influence of self-prioritization in different sensory modalities.

Sui and colleagues (2012) suggested a perceptual level for the tagging of labels and shapes; our data, however, suggest that the picture is somewhat more complex and the self-prioritization process is even more flexible. Self-prioritized processing has conceptual contents that could affect perception. Forming an arbitrary association between a concept and the self leads to prioritized processing of perceptual features matching the self-tagged concept. Note, however, that our finding still fits to the theoretical framework in which the self-prioritization effect has been integrated. In particular, Sui et al. (2012) suggested the biased competition model (Duncan, Humphreys, & Ward, 1997) as to explain the self-prioritization effect. That is, perception can be tuned to favor relevant stimuli (for example, stimuli that match current goals) and so perception is tuned to favor all self-relevant stimuli. Thus, it is not perceptual matching that defines self-prioritization, in the sense that a particular sensory input is matched against a particular formed perceptual memory entry. It seems that perceptual features are matched against a conceptual template prioritizing features that are tagged to the self.

Still one might assume a tagging of each single specific stimulus and the labels (maybe acquired during the first trials of an experiment). But in light of the amount of stimuli used in Experiment 1 and particular Experiment 2 this assumption seems quite implausible. For example, in Experiment 2 participants had the choice to remember and match one concept to one label or to remember 16 particular stimuli together with this label. In order to simplify

the task it seems plausible that most abstract representations for the mentioned stimuli are used by the participants.

Categorization and conceptual processing are mighty tools of our cognitive system as to structure and simplify the vast and complex amount of perceptual information presented to our sensory systems. From a functional viewpoint it thus follows naturally that self-prioritization also makes use of these mighty tools and therefore can modulate perception at a conceptual level.

## Electronic Supplementary Material

The electronic supplementary material is available with the online version of the article at <http://dx.doi.org/10.1027/1618-3169/a000307>

*ESM 1.* Raw data.

The raw data files are in the E-data-Aid format and include the complete, trial wise information per participant.

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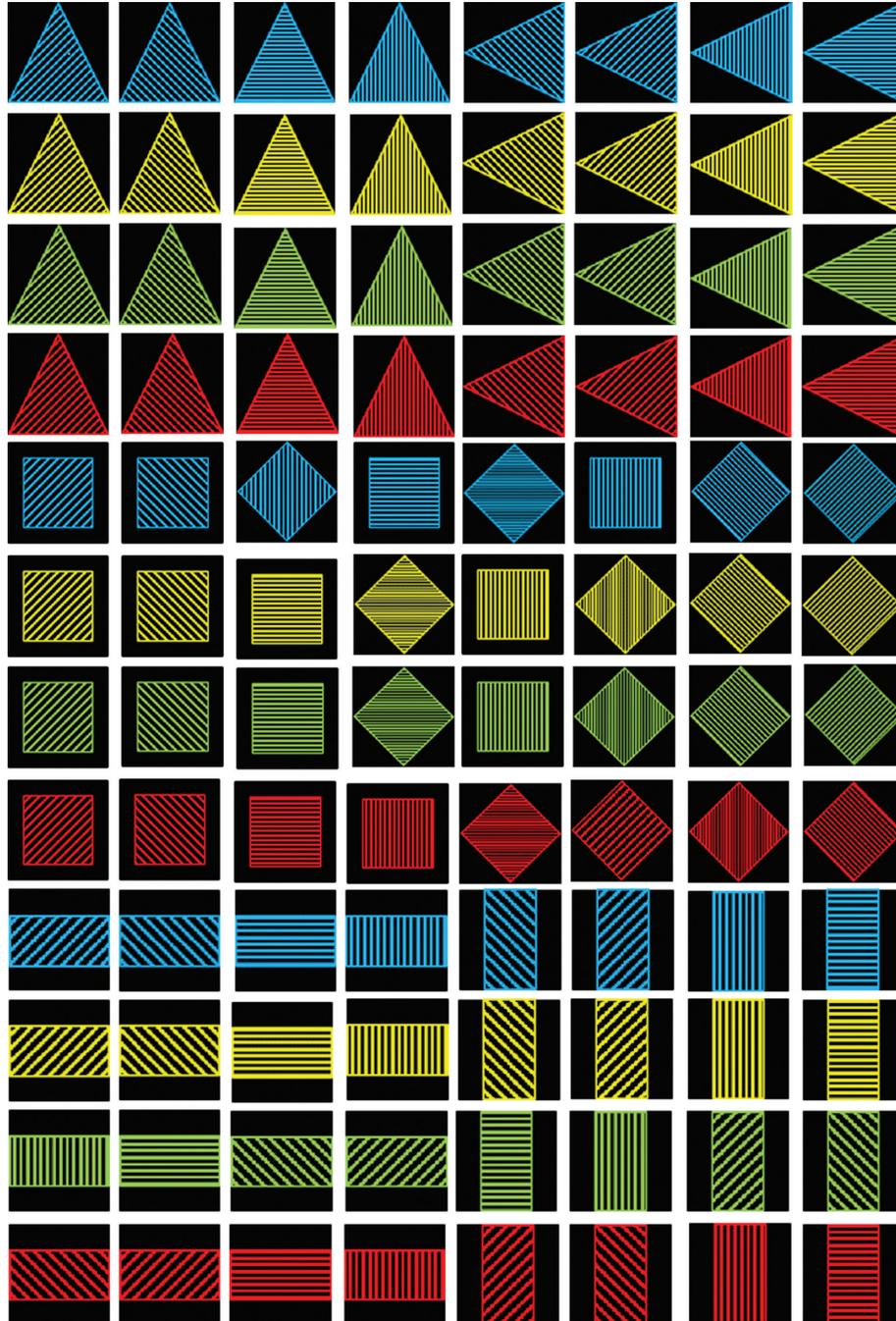
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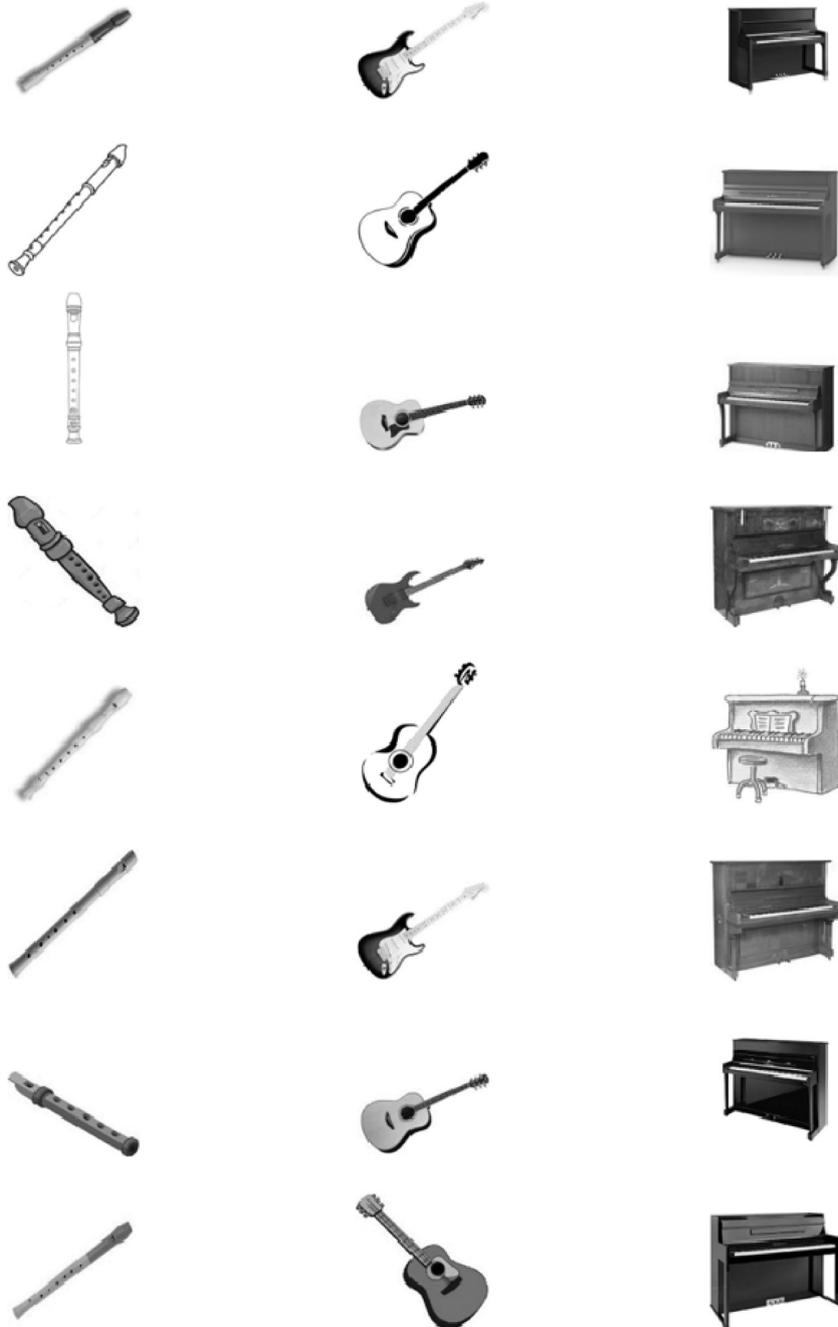
## Appendix A

## Used Shape Stimuli in the Matching Task in Experiment 1



## Appendix B

### Used Stimuli in the Visual Condition in Experiment 2



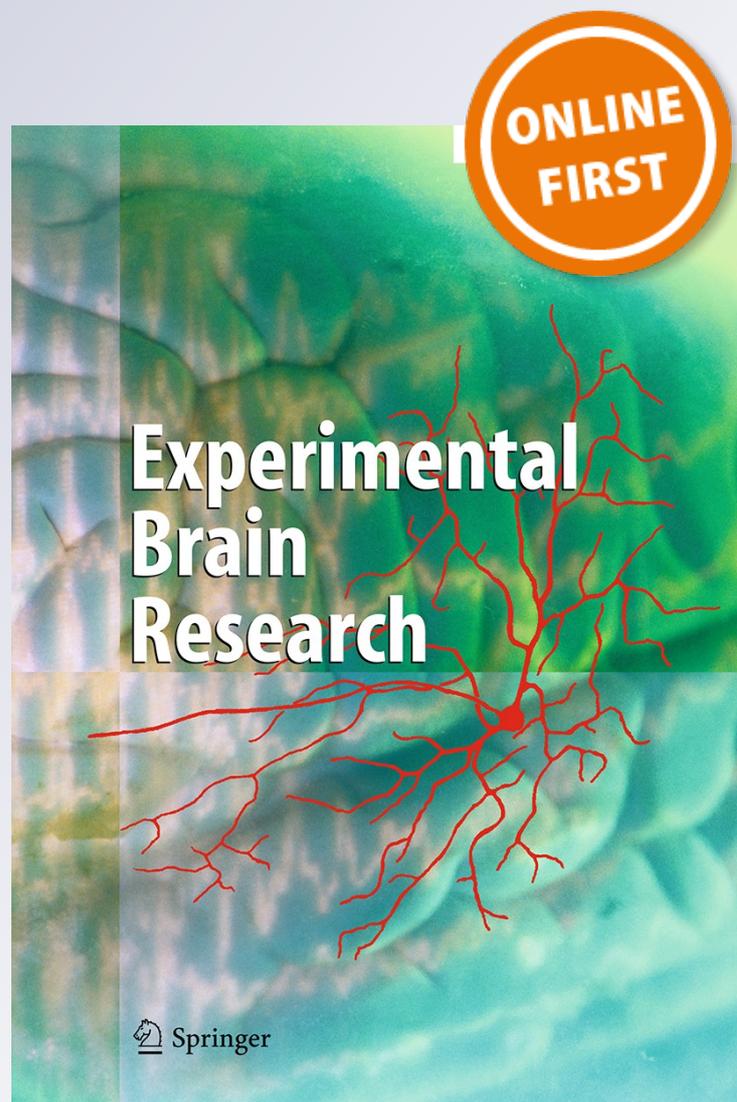
# *Self-prioritization in vision, audition, and touch*

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# Self-prioritization in vision, audition, and touch

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**Abstract** To investigate self-prioritization independently of stimulus familiarity, Sui et al. (J Exp Psychol Hum Percept Perform 38:1105–1117, 2012. doi:10.1037/a0029792) introduced a new paradigm in which different geometric shapes are arbitrarily associated with self-relevant (e.g., “I”) and neutral labels (e.g., “stranger”). It has now been repeatedly demonstrated that in a subsequently presented matching task, this association leads to faster and more accurate verifications of self-relevant shape–label pairings than neutral shape–label pairings. In order to assess whether this self-prioritization effect represents a general selection mechanism in human information processing, we examined whether it is limited to the visual modality. Therefore, besides visual stimuli, auditory and vibrotactile stimuli were also associated either to self-relevant or to neutral labels. The findings demonstrate that self-prioritization represents a general tendency influencing human information processing, one that operates across the senses. Our results also highlight a top–down component to self-prioritization.

**Keywords** Self-prioritization · Selection mechanism · Vision · Audition · Touch

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Sarah Schäfer and Ann-Katrin Wesslein have shared first authorship.

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## Introduction

Environmental information from different sources reaches our senses simultaneously. From this large amount of multi-sensory information, it is important to select just that information that is currently relevant, and to ignore that which is currently irrelevant. Self-relevance is an important feature that predestines a piece of information to be selected for further processing. Diverse findings show that self-relevant information bypasses attentional thresholds more easily than information that is not linked to the self (e.g., Bargh 1982; Moray 1959, for dichotic listening; Wuillemin and Richardson 1982, for the importance of expectation; Giesbrecht et al. 2009, for visual attentional blindness; Yang et al. 2013, for effects in visual search) and that attention is automatically captured and directed by information that is self-relevant (Alexopoulos et al. 2012).

So far in the field of self-prioritization research, self-relevant information has mostly consisted of the participant's own name, a picture of his or her face, or autobiographical information. Thus, the self-relevant stimuli typically used in these studies tend to have been highly overlearned and familiar and are typically compared to non-self-relevant stimuli which are not overlearned or nearly as familiar as the self-relevant ones. In order to avoid the confound of familiarity and self-relevance, Sui et al. (2012) introduced a paradigm in which, through training, simple geometric shapes are associated with the self, a familiar person, or a neutral stimulus by presenting the shape–label mappings on the screen (e.g., “[the participant's best friend's name] is a circle. You are a triangle. And a stranger is represented by a square.”). After this association phase, performance in self-relevant trials was enhanced as compared to performance in other-relevant trials (i.e., the participant's best friend and

a stranger in the above example), thus demonstrating self-prioritization. In detail, after the association phase, participants performed a matching task in which they had to judge whether or not presented shape–label pairings (i.e., the label “you” presented with a triangle) were correct according to the learned associations. The results showed that verifications of correct self-relevant trials were performed faster and more accurately than verifications of correct other-relevant trials, thus reflecting the self-prioritization effect (SPE).

Neurological investigations of the SPE using functional magnetic resonance imaging (fMRI) have revealed activation in separate brain regions for self-relevant (the ventral medial prefrontal cortex [vmPFC] and the left posterior superior temporal sulcus [LpSTS]) and non-self-relevant content (the dorsal frontoparietal control network), and a correlation of the SPE with a coupling of vmPFC and LpSTS (Sui et al. 2013b). Moreover, partially overlapping brain activations while suppressing self-associated or perceptually salient distractors, respectively, indicate that newly acquired self-assignments affect neural activation comparably (though that is not to say equivalently) to perceptual salience (Sui et al. 2013a).

To date, the SPE has been replicated several times in visual matching tasks and has been generalized to different labels (see Sui et al. 2012 for findings concerning the SPE's independence from word length, frequency, and familiarity; see also Schäfer et al. 2015; Sui et al. 2013b). Furthermore, the effect has been extended from perception to action. For this purpose, simple movement directions (i.e., up, down, left, and right) were assigned to the participant's self, to his/her mother, to a stranger, or to a neutral label; in the following trials, participants executed a movement (triggered by a cue) which was followed by a label. The participants then had to judge whether the particular movement–label pairing matched or not. Comparing performance in matching trials, an SPE was observed: That is, responses toward self-relevant movement–label pairings were faster and more accurate than responses toward other-relevant movement–label pairings (Frings and Wentura 2014).

According to the extension of the SPE from visual perception to action, one could expect an influence of self-relevance on information processing in modalities other than vision. In particular, there is a rich body of research dealing with the question of what we consider to be our *self* and how the tactile sense defines the border of the self (Galace and Spence 2014). Many studies dealing with the so-called full-body illusion indicate somatosensory sensations as a relevant factor to discriminate our self from the environment (e.g., Ehrsson 2007; Lenggenhager et al. 2007). “Bodily self-consciousness” is substantially dependent on visual as well as somatosensory cues (Lenggenhager et al. 2009), and tactile input is consulted to build up a feeling of

body ownership (Ehrsson 2012). What is more, tactile input can (among other things) be separated (at least to a certain extent) into discriminative and emotional components, mediated by different peripheral nerve fibers (McGlone et al. 2007), indicating that emotional characteristics of tactile input are assessed and differentiated. In sum, one could expect an influence of self-relevance on tactile information processing even stronger than the influence on visual processing. That is, empirical research is consistent with the view that the SPE might vary between the senses.

Assuming differences in the influence of self-relevance according to the sensory modality, it is also reasonable to consider that the SPE may be absent outside vision, since the same holds for other phenomena than self-prioritization when compared between the senses (see, e.g., Barsalou et al. 2003). Note that the assessment of self-relevance effects in the matching paradigm is characterized by the assignment of formerly neutral stimuli to particular labels. Remarkably, these neutral stimuli have up to now always been presented visually, resulting in a to-be-learned combination of two visually presented stimuli (e.g., a shape and a label). Even the extension of the SPE to movements implied the combination of visually presented labels and visual equivalents of the movements (i.e., the mouse cursor following the participant's movement). In the present study, the matching paradigm was implemented with the to-be-associated neutral stimuli presented to sensory modalities other than vision (and with no visual component or counterpart). Importantly, in the field of self-experience, multisensory integration is stated to be a necessary condition for self-identification, and discrepancies between the pieces of information reaching different sensory modalities are postulated to reduce the experience of ownership (Tsakiris 2010). Assuming that sensory integration and overlap are required for self-referential processing, possibly the combination of a (visually presented) label and a visually presented stimulus is necessary to find effects on associative learning. Hence, the association of visually presented labels with auditory or tactile stimuli might be unaffected by self-relevance, because the sensory overlap between the stimuli is missing. That is, it is possible that no SPE would be found with auditory or tactile neutral stimuli in the matching paradigm used previously with just visual stimuli.

In addition, whereas visual stimuli may occur in the periphery, self-relevant tactile input is always spatially close to the own body and might therefore per se be judged as self-relevant. That is, studies on self-experience and on bodily illusions typically do not deal with externally presented stimuli. Thus, since tactile stimulation always occurs close to the bodily self, it seems plausible that there is no differentiation between self- and other-relevant inputs in touch. Accordingly, in a study designed to assess people's identification of their own hand, participants failed

to recognize their own hand from among other objects if they were not explicitly informed that they might see their own hand (Wuillemin and Richardson 1982). Hence, again, one may argue that the SPE should be absent in the tactile modality.

Importantly, however, the extension of the SPE from visual perception to action might be interpreted to indicate that self-prioritization represents a *general* effect. After all, effects of self-relevance in different sensory modalities have often been observed in the literature prior to the introduction of the matching task to assess self-prioritization. For example, the so-called “cocktail party effect” was first observed in the dichotic listening task (Moray 1959; see Conway et al. 2001 for the influence of working-memory capacity), indicating that auditory stimuli presented from an ignored location/“channel” can attract attention if they happen to be self-relevant (see also Bargh 1982). Additionally, magnetoencephalographic examinations of the auditory cortex have revealed that self-triggered sounds are distinguished from externally triggered sounds, indicating a neuronal separation (Martikainen et al. 2005). Thus, assuming that the SPE represents effects of self-relevance as measured independently of familiarity (which does not hold for previous self-relevant studies using, e.g., the participant’s name, or picture, as self-relevant stimuli), then it should equally emerge for visual, auditory, and tactile stimuli.

When introducing the matching paradigm, Sui and her colleagues suggested that the biased competition model of attention (Desimone and Duncan 1995; Duncan et al. 1997) might underlie the SPE. In brief, the idea is that sensory input in the primary (visual) cortex can be boosted by top-down influences. Self-relevance—even if only recently and arbitrarily acquired—can be seen as such a top-down influence, i.e., the default value of the cognitive system is to prioritize self-relevant information at quite early stages of (visual) processing. This mechanism might well operate for the other sensory modalities. Based on this notion, together with the assumption that the SPE in the matching paradigm reflects previous effects of self-relevance, it was hypothesized that top-down influences can also boost self-relevant information in senses other than vision. Such a result would support the claim that this “self-relevance boost” reflects a general and modality-independent mechanism. In this sense, we predict that the SPE should emerge in different sensory modalities.

In order to explore the hypothesis that a general, modality-independent component of the self-prioritization process exists, we adapted Sui et al.’s (2012) paradigm in such a way that formerly neutral sounds or vibrotactile rhythms, rather than visually presented geometric forms, were associated with the participant’s self, a familiar person, and a

neutral stimulus. Investigating the SPE for audition and touch and comparing it between the senses, the current study aimed to provide insights on self-relevant information processing irrespective of the modality.

## Overview

In Experiment 1, we assessed the visual SPE using an adapted version of the self-prioritization paradigm (cf. Sui et al. 2012). That is, participants learned the mapping of three geometric shapes to the self (i.e., the label “I”) versus to two other-relevant labels (i.e., the labels “mother” and “chair”) in a sequential learning phase. After this learning phase, the participants were presented with one of the stimuli, followed by one of the labels. Their task was to indicate whether or not the stimulus–label combinations matched the association rules that had been learned previously (matching task). Experiment 2 constituted a replication of Experiment 1, with the only difference being that neutral sounds were now used instead of geometric shapes. Meanwhile, in Experiment 3, vibrotactile rhythms were used as stimuli. Experiments 2 and 3 enabled us to test whether the SPE—reflecting a pure measure of self-prioritization apart from familiarity—also occurs in the auditory and tactile modalities.

In all three experiments, the SPE was indicated by faster and more accurate responses in those trials with the self-associated stimulus (i.e., the stimulus associated with the label “I”) compared to responses in trials with one of the other-associated stimuli (i.e., the stimuli associated with the label “mother” or “chair”). As in previous research, error rates were analyzed using signal detection indices, but mean reaction times (RTs) were the main dependent variable. Note that all three experiments were carried out according to the principles of the Declaration of Helsinki, on the basis of informed consent.

## Experiment 1

To enable direct comparisons of the SPE between the modalities, we used variants of the matching paradigm in which the to-be-associated stimuli were explicitly presented during the learning phase, and with the stimulus–label assignments presented sequentially. This was not the case in previous visual experiments that have used this paradigm in which the participants learned the stimulus–label mappings by means of simultaneously presented sentences (e.g., see Sui et al. 2012). Hence, Experiment 1 was conducted as a kind of control condition whereby three geometric forms, namely a square, a triangle, and a circle, were associated with the labels “I,” “mother,” and “chair”

in a learning phase in which labels and stimuli were explicitly presented.

## Methods

### Participants

Thirty students (26 females) with a median age of 22 years (ranging from 18 to 29 years) participated, all having normal or corrected-to-normal vision. The mean error rate of two participants and the average RT of three participants constituted an outlier according to Tukey (1977) when compared to the sample distribution of the mean error rates or average RTs of all participants. The data from these five participants were therefore excluded from the data analyses.

The SPEs were rather large in previous studies ( $d_z > 0.81$  in Sui et al. 2012). Given  $N = 25$ ,  $\alpha = .05$ , and a power of  $1 - \beta = .80$ , an effect of size  $d_z \geq .58$  could be detected (G\*Power 3.1.3, Faul et al. 2007).

### Design

The experiment consisted of a 3 (visual stimulus: *self-associated* vs. *mother-associated* vs. *chair-associated*)  $\times$  2 (matching condition: *matching* vs. *non-matching*) within-participant design.

### Apparatus and materials

The experiment was conducted on PCs with 24"-TFT screens using standard computer mice. The experiment was run by E-Prime 2.0 software. The stimuli consisted of visual geometric shapes. The labels used were the German word "Ich" [I] as a self-relevant stimulus, the German word "Mutter" [mother] as a familiar stimulus, and the German word "Stuhl" [chair] as a neutral stimulus. These words were presented in white against a black background and in Courier New typeface at a viewing distance of 50 cm, resulting in a visual angle of about  $0.7^\circ$ . In the matching-task trials, the geometric shapes, the labels, and a fixation cross at the start of each trial were presented from the center of the computer screen, subtending  $5.7^\circ \times 5.7^\circ$  visual angle for the geometric shapes. The assignment of the geometric shapes to the labels was balanced across participants following a Latin square design.

### Procedure

Participants were tested in soundproofed rooms. The task instructions were briefly summarized by the experimenter

and were also presented on the screen; responses involved presses of the right and left button of the computer mouse.

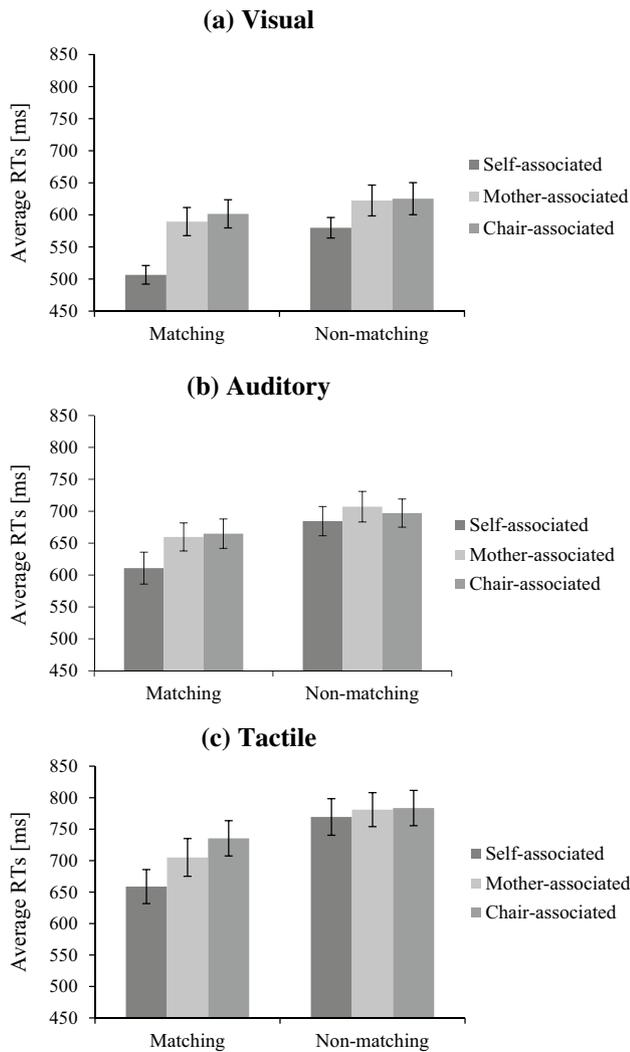
At the beginning of the experimental session, the participants learned the assignments of the labels (*I* vs. *mother* vs. *chair*) to the geometric shapes (*triangle* vs. *square* vs. *circle*). The participants had to remember the stimulus–label assignments and were told that they had to evaluate stimulus–label pairings with respect to this assignment in the second phase of the study. A trial of the learning phase started with the presentation of a label. After 500 ms presenting the label only, the to-be-associated stimulus was presented for 2500 ms (with the label still visible) and followed by a blank screen for 2000 ms. Each stimulus–label pairing was presented four times during the learning phase, resulting in a total of 12 trials.

Closely following Sui et al.'s (2012) procedure, the participants next went through a practice phase of the matching task. Therefore, participants were instructed to place their right index finger on the left mouse button (matching response) and their right middle finger on the right mouse button (non-matching response). Each trial of the practice phase started with the presentation of a black screen (500 ms), followed by a fixation cross (again 500 ms). The visual stimulus was presented for 500 ms and followed by the label which remained on the screen until the participant responded. At the end of each trial, participants received feedback whether their response had been correct or not.

After 12 practice trials (six matching and six non-matching trials), the participants started the experimental phase. Again, their task was to judge whether the displayed stimulus–label pairing corresponded to the initially learned assignment (press the left mouse button) or not (press the right mouse button). The participants were only provided with feedback when their response was incorrect. The experimental phase consisted of 192 trials presented in random order. In detail, each label was presented in 64 trials, half of them with matching pairings and half of them with non-matching pairings, resulting in 32 matching and 32 non-matching trials for each label.

## Results

For all of the analyses reported in Experiments 1–3, only correct responses with RTs above 100 ms and below three interquartile ranges above the third quartile of the overall distribution of correct RTs (Tukey 1977) were used for the RT analysis. Further, for all of the statistical analyses reported here, a significance level of  $\alpha = .05$  was specified. In Experiment 1, averaged across participants, 96.2 % of the trials were selected for RT analysis; 3.1 % of the trials were excluded because of erroneous responses; and 0.8 % due to the RT outlier criteria.



**Fig. 1** Mean RTs as a function of the particular stimulus (*self-* vs. *mother-* vs. *chair-associated*) and matching condition (*matching* vs. *non-matching*) **a** with visual stimuli (Experiment 1), **b** with auditory stimuli (Experiment 2), and **c** with tactile stimuli (Experiment 3). The error bars indicate the SEs of the means

Average RTs

The RT data were submitted to a 3 (visual stimulus: *self-* vs. *mother-* vs. *chair-associated*) × 2 (matching condition: *matching* vs. *non-matching*) within-participant MANOVA (see O’Brien and Kaiser 1985, for the use of MANOVA to analyze repeated-measures designs). The main effects of visual stimulus,  $F(2, 23) = 10.68, p = .001, \eta_p^2 = .48$ , and matching condition,  $F(1, 24) = 27.97, p < .001, \eta_p^2 = .54$ , were both significant. Additionally, there was a significant visual stimulus × matching condition interaction,  $F(2, 23) = 6.24, p = .007, \eta_p^2 = .35$ .

To probe the interaction of label and matching condition and following Sui and colleagues’ logic according to the SPE, we analyzed matching and non-matching trials separately (see Fig. 1a). As mentioned above, the effect was indicated by faster responses in matching trials with the self-associated stimulus (i.e., the stimulus associated with the label “I”) compared to responses in matching trials with one of the other-associated stimuli (i.e., the stimuli associated with the label “mother” or “chair”), which was reflected by a Helmert contrast. In a one-factorial MANOVA with matching trials, the within-participant factor of visual stimulus revealed a significant Helmert contrast,  $F(1, 24) = 22.87, p < .001, \eta_p^2 = .49 (dz = .96)$ , indicating a significant SPE in the RT data (see Fig. 1a). In non-matching trials, this Helmert contrast was also significant,  $F(1, 24) = 12.86, p = .001, \eta_p^2 = .35$ , indicating that even in non-matching trials RTs depended on the stimulus association.

Sensitivity measures

Mean error rates for Experiments 1–3 are shown in Table 1. The error data were analyzed using signal detection sensitivity indices for each stimulus condition (cf. Sui et al. 2012). To this end, we considered correct responses in

**Table 1** Error rates (in %) as a function of matching condition (*matching* vs. *non-matching*), stimulus association (*self-associated* vs. *mother-associated* vs. *chair-associated*), and sensory modality (*vision* vs. *audition* vs. *touch*)

Sensory modality	Matching condition					
	Matching			Non-matching		
	Stimulus association					
	Self	Mother	Chair	Self	Mother	Chair
Vision (Exp. 1)	2.1 (2.8)	4.6 (3.6)	4.3 (5.7)	1.8 (2.9)	3.6 (3.5)	2.1 (2.8)
Audition (Exp. 2)	6.7 (8.9)	8.5 (6.5)	9.4 (8.3)	6.3 (5.8)	9.0 (8.1)	7.8 (6.0)
Touch (Exp. 3)	4.0 (5.3)	3.9 (6.5)	6.0 (5.6)	4.9 (6.8)	4.3 (4.9)	4.7 (5.5)

Standard deviations in brackets

matching trials to represent hits and erroneous responses in matching trials to represent misses. Correct responses in non-matching trials were considered correct rejections, and erroneous responses were treated as false alarms. Following the so-called log-linear approach to account for cases with 100 % hits or 0 % false alarms (see Hautus 1995; Stanislaw and Todorov 1999), we then computed  $d'$  as a measure of sensitivity. That is, we added 0.5 to the number of hits and the number of false alarms, and we added 1 to the number of signal trials and the number of noise trials before calculating the hit and false alarm rates.

The resulting  $d'$  indices were submitted to a one-factorial MANOVA with three levels (visual stimulus: *self-* vs. *mother-* vs. *chair-associated*). The relevant Helmert contrast was significant,  $F(1, 24) = 11.50$ ,  $p = .002$ ,  $\eta_p^2 = .32$ , indicating a significant SPE in sensitivity measures.

## Experiment 2

In Experiment 2, the participants learned to associate three different auditory stimuli to the labels “I,” “mother,” and “chair.” That is, for the first time, auditory stimuli were used to test whether or not there is an auditory SPE for formerly neutral stimuli that became associated with the self. The design and procedure were the same as in Experiment 1 with the only exceptions concerning small adaptations of the experimental setup and stimulus presentation resulting from the change in the stimulus modality.

## Methods

### Participants

Thirty-three volunteers (20 females) were recruited at the University of Trier in exchange for course credit. Their median age was 22 years (ranging from 18 to 27 years), and all participants had normal or corrected-to-normal vision. The mean error rate of two participants constituted an outlier according to Tukey (1977) when compared to the sample distribution of the mean error rates of all participants. The data from these participants were therefore excluded from the data analyses.

Given  $N = 31$ ,  $\alpha = .05$ , and a power of  $1 - \beta = .80$ , an effect of size  $d_z \geq .52$  could be detected (G\*Power 3.1.3, Faul et al. 2007).

### Apparatus and materials

The apparatus was the same as in Experiment 1 with the exception that auditory stimuli served as stimuli. The stimuli consisted of instrumental tones as generated by a flute, a snare drum, and a woodblock (percussion instrument). In a pilot

study, 30 participants had rated the subjective valence of eight different instrumental sounds on a nine-point Likert-scale. We selected three sounds of which the mean ratings did not differ significantly from *neutral* with all  $ps \geq .190$ ;  $M_{\text{flute}} = 4.92$  (SD = 1.62);  $M_{\text{snare drum}} = 4.93$  (SD = .93);  $M_{\text{woodblock}} = 4.65$  (SD = 1.43), indicating that the sounds used were neutral in valence. The auditory stimuli on a given trial had an intensity of approximately 50 dB SPL and were presented for 300 ms via headphones. In the matching-task trials, the fixation cross presented at the start of each trial and the label were both presented 21.0° from the upper border of the screen.

### Procedure

The procedure was essentially the same as in Experiment 1. Yet, in the learning phase, after presenting the label for 500 ms, the to-be-associated stimulus was presented for 300 ms (with the label still visible), and after the presentation of the sound, the label remained on the screen for another 2200 ms, resulting in a total label presentation time of 3000 ms.

## Results

Averaged across participants, 92.1 % of the trials were selected for RT analysis; 7.9 % of the trials were excluded because of erroneous responses; and 0 % due to the RT outlier criteria.

### Average RTs

In a 3 (auditory stimulus: *self-* vs. *mother-* vs. *chair-associated*)  $\times$  2 (matching condition: *matching* vs. *non-matching*) within-participant MANOVA, the main effect of auditory stimulus just missed the conventional criterion of significance,  $F(2, 29) = 3.15$ ,  $p = .058$ ,  $\eta_p^2 = .18$ . The main effect of matching condition was significant,  $F(1, 30) = 40.62$ ,  $p < .001$ ,  $\eta_p^2 = .58$  and, importantly, the interaction between the factors of auditory stimulus and matching condition was significant too,  $F(2, 29) = 3.46$ ,  $p = .045$ ,  $\eta_p^2 = .19$ , thus suggesting that the RT differences for the labels differed for matching and non-matching trials.

Analyzing matching and non-matching trials separately, a one-factorial MANOVA with matching trials and the within-participant factor of auditory stimulus (*self-* vs. *mother-* vs. *chair-associated*) revealed a significant Helmert contrast,  $F(1, 30) = 8.16$ ,  $p = .008$ ,  $\eta_p^2 = .21$  ( $d_z = .51$ ), meaning that RTs were shorter in self-relevant matching trials than in other-relevant matching trials. In non-matching trials, this Helmert contrast was not significant,  $F(1, 30) = 2.17$ ,  $p = .151$ ,  $\eta_p^2 = .07$ , showing that RTs in non-matching trials were not affected by the association of the stimuli.

### Sensitivity measures

Once again, error rates were analyzed using signal detection indices for each label condition. A one-factorial MANOVA with three levels (auditory stimulus: *self-* vs. *mother-* vs. *chair-associated*) yielded a significant Helmert contrast,  $F(1, 30) = 5.41$ ,  $p = .027$ ,  $\eta_p^2 = .15$ , indicating a higher sensitivity in trials with the self-relevant stimulus than in trials with other-relevant stimuli.

## Experiment 3

In Experiment 3, we assessed the SPE in touch. That is, three different vibrotactile rhythms were now associated with the labels “I,” “mother,” and “chair.” The design and procedure were essentially the same as those in Experiments 1 and 2.

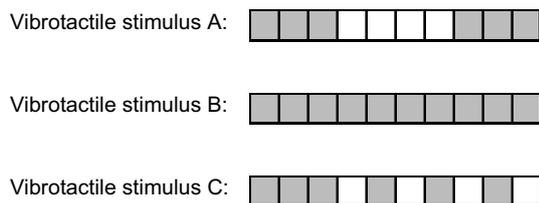
### Methods

#### Participants

Twenty-four students (22 females) at the University of Trier participated in the experiment in exchange for course credit. Their median age was 21 years (ranging from 18 to 25 years), and all participants had normal or corrected-to-normal vision. Given  $N = 24$ ,  $\alpha = .05$ , and a power of  $1 - \beta = .80$ , an effect of size  $d_z \geq .60$  could be detected (G\*Power 3.1.3, Faul et al. 2007). Note that the SPEs in Sui et al. (2012) were  $d_z > .81$ .

#### Apparatus and materials

The apparatus was the same as in Experiments 1 and 2. Additionally, in this experiment, E-Prime controlled the presentation of the vibrotactile stimuli via a serial interface. That is, the vibrotactile stimuli were delivered by means of a tactor (Model C-2, Engineering Acoustic, Inc.) which was driven independently from the PC by an individual standard amplifier (Power Amplifier Module PM40C, t.amp).



**Fig. 2** Schematic illustration of the three vibrotactile stimuli, each consisting of ten 50-ms intervals. Vibrations are indicated by gray intervals, pauses by white intervals

This tactor was 1.17" in diameter and 0.30" thick, and it was fastened to the side of the participant's left palm by means of a Velcro strip.

Three vibrotactile stimuli with different rhythms were used throughout the experiment (see Fig. 2 for a schematic illustration). The first vibration comprised two 150-ms pulses separated by a 200-ms pause (Stimulus A). The second vibration consisted of a continuous 500-ms pulse (Stimulus B), and the third vibration consisted of a 150-ms pulse followed by three 50-ms pulses, whereby each of the four pulses was followed by a 50-ms pause (Stimulus C). The tactile stimuli on a given trial were presented for 500 ms.

#### Procedure

In order to reduce the amount of environmental noise to a minimum, participants were tested in a completely light- and soundproofed room. They had their left hand positioned at their body midline (i.e., in the direction where the head was oriented). To limit and control for any potential auditory cues emitted by the operation of the transducers, the participants' hands were lifted up by placing their left wrist on an armrest. Additionally, white noise was presented via headphones to rule out any influence of auditory signals (e.g., those attributable to the activation of the transducers). In each trial, a black screen (500 ms), a fixation cross (500 ms), a tactile stimulus (500 ms), another fixation cross (50 ms), and a label were sequentially presented. The label remained on the screen until the participant responded.

### Results

Averaged across participants, 94.3 % of the trials were selected for RT analysis; 4.6 % of the trials were excluded because of erroneous responses; and 1.1 % due to the RT outlier criteria.

#### Average RTs

A 3 (vibrotactile stimulus: *self-* vs. *mother-* vs. *chair-associated*)  $\times$  2 (matching condition: *matching* vs. *non-matching*) within-participant MANOVA revealed a nonsignificant main effect of the vibrotactile stimulus,  $F(2, 22) = 2.80$ ,  $p = .083$ ,  $\eta_p^2 = .20$ . Nevertheless, a significant main effect of matching condition was observed,  $F(1, 23) = 50.95$ ,  $p < .001$ ,  $\eta_p^2 = .69$ , which was qualified by a significant interaction with the vibrotactile stimulus factor,  $F(2, 22) = 4.60$ ,  $p = .021$ ,  $\eta_p^2 = .30$ . Analyzing matching and non-matching trials separately, a one-factorial MANOVA with matching trials and the within-participant factor of vibrotactile stimulus revealed a significant Helmert contrast

(self-relevant vs. other-relevant matching trials),  $F(1, 23) = 9.44$ ,  $p = .005$ ,  $\eta_p^2 = .29$  ( $d_z = .64$ ), reflecting a significant SPE in the RT data (see Fig. 1b). In non-matching trials, this Helmert contrast was nonsignificant,  $F < 1$ , thus revealing that RTs in non-matching trials were not affected by the association of the stimuli to self- or other-relevant labels.

### Sensitivity measures

To analyze the error rates, sensitivity indices  $d'$  were again submitted to a one-factorial MANOVA with three levels (vibrotactile stimulus: *self-* vs. *mother-* vs. *chair-associated*). The Helmert contrast was not significant,  $F < 1$ , indicating no significant SPE in sensitivity measures.

### Comparison of the SPE across modalities

To compare the size of the SPE in vision, audition, and touch, the data of all participants included in the analyses of Experiments 1–3 were submitted to a one-factorial ANOVA with the between-participant factor of stimulus modality (*vision* vs. *audition* vs. *touch*). As the dependent variable, the SPE was computed by subtracting the mean RT/ $d'$  in trials with the self-associated stimulus from the average RT/ $d'$  in trials with one of the other-associated stimuli. We conducted one ANOVA for SPEs based on RTs and the same ANOVA for SPEs based on  $d'$ . To control for processing differences between the senses, we adjusted each participant's SPE, dividing it by his/her mean RT or his/her mean  $d'$ .<sup>1</sup> With regard to the RT data, the ANOVA revealed no significant main effect of stimulus modality (*vision* vs. *audition* vs. *touch*),  $F(2, 77) = 1.66$ ,  $p = .198$ ,  $\eta_p^2 = .04$ , indicating that the adjusted RT-based SPE did not differ significantly between the senses.<sup>2</sup> With regard to the sensitivity measures, the adjusted  $d'$ -based SPE did also not differ significantly between the stimulus modalities,  $F < 1$ . Taken together, these analyses suggest that modality did not moderate the SPE.

<sup>1</sup> For all three stimulus modality conditions, the analyses with the adjusted SPEs replicated the reported effects [in RTs:  $t(24) = 5.18$ ,  $p < .001$ ,  $d = 1.04$ , for vision,  $t(30) = 3.25$ ,  $p = .003$ ,  $d = 0.58$ , for audition, and  $t(23) = 3.25$ ,  $p = .004$ ,  $d = 0.66$ , for touch; in  $d'$ :  $t(24) = -3.43$ ,  $p = .002$ ,  $d = 0.69$ , for vision,  $t(30) = -2.01$ ,  $p = .027$  (one-tailed),  $d = 0.36$ , for audition, and  $t(23) = -0.58$ ,  $p = .571$ ,  $d = 0.12$ , for touch].

<sup>2</sup> Note that the power to detect a large effect ( $f = 0.4$ ) between the stimulus modalities, given an  $\alpha$  value of .05 and  $N = 80$ , was  $1 - \beta = .89$  (calculations performed with G\*Power 3.1.3; Faul et al. 2007).

To provide further support for this conclusion, we calculated Bayes factors using the Bayes ANOVA module of JASP (Love et al. 2015). The Bayes factor in favor of the null model is  $BF_{01} = 2.55$  for the adjusted RT-based SPE and  $BF_{01} = 5.18$  for the adjusted  $d'$ -based SPE. According to the rules of thumb given by Raftery (1995), the former value is considered “weak” evidence for the null hypothesis, whereas the latter is categorized as “positive” evidence.

Moreover, to approach the question of whether the processes underlying the SPE differ between vision, audition, and touch, we analyzed the RT-based SPE's dependence on the duration of mean RTs by a distribution analysis (delta plots). Therefore, mean RTs of correct responses were vincentized (Ratcliff 1979) separately for each of the conditions of the 3 (stimulus: *self-* vs. *mother-* vs. *chair-associated*)  $\times$  2 (matching condition: *matching* vs. *non-matching*) design. Individual mean RTs were derived for each quintile of the rank-ordered raw RT data. To reduce complexity, we used the RT-based SPE (rather than mean RTs for each quintile and condition) as the dependent variable. A 5 (quintile)  $\times$  3 (stimulus modality: *vision* vs. *audition* vs. *touch*) MANOVA for repeated measures with SPE as the dependent variable yielded a significant main effect of quintile,  $F(4, 74) = 8.97$ ,  $p < .001$ ,  $\eta_p^2 = .327$ , which was not moderated by stimulus modality,  $F < 1$ . Only the linear trend was significant,  $F(1, 77) = 17.93$ ,  $p < .001$ ,  $\eta_p^2 = .189$  ( $F < 1.16$  for the moderation by modality). This indicates that the SPE increased significantly with the duration of mean RTs (a pattern routinely expected for RT effects, e.g., Schwarz and Miller 2012) and, moreover, that this increase is independent of the stimulus modality.

### General discussion

In the present study, we investigated the SPE using a matching task in vision, audition, and touch (Experiments 1–3, respectively). Specifically, we compared performance in those trials with a stimulus that had been associated with the self to performance in trials with other-associated stimuli. In all three experiments, as hypothesized, performance in self-associated trials was faster than performance in other-associated trials. That is, the typical pattern of data was replicated for the visual modality, and it was, for the first time, demonstrated in the auditory and tactile modalities as well. Note that the learning phase in all three experiments reported here was slightly different from that commonly used in the matching paradigm. That is, the to-be-associated stimuli were not introduced semantically (i.e., presenting the word “triangle”), but directly presented (i.e., presenting a triangle), and the shape–label associations were presented sequentially in random order in the learning phase. Still, in line with previous research,

a prioritization of self-relevant pairings occurred irrespective of the stimulus modality. Furthermore, the results are in line with the assumption of top-down influences on information processing in the visual cortex as stated by the biased competition model of attention (Desimone and Duncan 1995). Additionally, the results may reflect similar modulatory top-down influences on the sensory input in auditory and somatosensory cortex.

Taken together, the finding of comparably sized SPEs in the different senses suggests that self-prioritization represents a general top-down influence on sensory processing. This is in line with previous research highlighting the importance of self-relevance in different sensory modalities, namely audition (e.g., the “cocktail party effect”; Moray 1959) and touch (e.g., the full-body illusion; Ehrsson 2007; Lenggenhager et al. 2007). Yet, previous findings in different modalities did not use the matching paradigm to assess self-prioritization independently from familiarity of the stimulus materials. Rather, the participant's own name was, for example, often used as the self-relevant stimulus. In contrast, the matching paradigm represents a tool for measuring self-relevance independently from familiarity, because here formerly neutral stimuli become associated with the self versus others throughout the experimental procedure. Hence, the supramodal observation of self-prioritization in the current experiments reflects original evidence for a *general* tendency to prioritize arbitrarily tagged self-relevant contents independently of familiarity. This strengthens the assumption that self-relevance can be an important mechanism in selection as to guide human behavior in a perceptually complex environment. The *top-down* component of the SPE in the matching task has previously been interpreted to directly impact sensory input. For example, an interaction of the effect with visual degradation, assumed to modulate early visual processing (Sui et al. 2012), and postulated neuronal as well as behavioral parallels of self-relevance and perceptual saliency (Sui et al. 2013a) supports this hypothesis. Nevertheless, other findings suggest that the SPE may not only affect the sensory input but potentially later stages of information processing as well. For example, a memory advantage for self-related pairings was shown, indicating a better individuation of self-relevant associations rather than a perceptual benefit (Fuentes et al. 2015) and a prioritization of abstract concepts rather than specific percepts emphasizes conceptual components of self-prioritization (Schäfer et al. 2015).

There are some methodological drawbacks with regard to the current study that should be mentioned. First, significant SPEs in all three experiments were found in the RT data but not in the sensitivity indices. In the sensitivity data, significant self-prioritization was observed in audition (Experiment 2) and vision (Experiment 1). Yet, no significant SPE was documented in touch (Experiment 3). Still,

importantly, there was no evidence for any speed accuracy trade-off. This absence of a SPE with regard to the sensitivity may be related to the consistently high accuracy (indicated by low error rates in all conditions). Second, the power to detect an effect of the sensory modalities on the size of the SPE was only acceptable for large effect sizes in the current study (i.e., if there are modality-specific effects on the SPE with middle or low effect sizes, we could have missed them due to power issues). Yet, the conclusion that the SPE is independent of the sensory modalities is further supported by another statistical approach (namely the Bayesian approach). Nonetheless, our results clearly show that self-prioritization influences information processing in different sensory modalities.

Overall, the current approach and results open the door to a number of intriguing questions regarding self-prioritization processes. For example, the RT distribution analysis revealed that the increase in the SPE with mean RTs was not modulated by the sensory modality. This provides only indicative evidence that the basic processes causing the SPE are amodal so that the results cannot unequivocally be taken to imply that self-prioritization is attributable to the same processes in all (tested) sensory modalities. As the current experiment was not conducted to investigate the contribution of specific cognitive processes to the SPE, future research is needed in order to test whether the SPE is modulated by the same factors in all three sensory modalities (e.g., whether the degradation of sensory input bolsters the SPE in audition and touch in the same way as it has been observed for vision).

In addition, the locus of the SPE needs further investigation. In particular, Schäfer et al. (2015) demonstrated that an abstract representation of a stimulus is mapped onto the to-be-associated label. Taken together with the findings of the current research, this raises the question of whether the association of a stimulus to the self leads to its prioritization on a supramodal level. To test this question, future research may use a crossmodal variant of the matching task.

In summary, the behavioral data obtained in the present study extend the finding that self-prioritization influences human information processing from the visual modality to the sensory modalities of audition and touch. That is, we present the first study to show that auditory and tactile stimuli that become associated with the self (albeit arbitrarily) are prioritized when compared to other-associated stimuli within the same modality. In conclusion, self-prioritization represents a top-down mechanism influencing the processing of sensory input across vision, audition, and touch.

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## Compliance with ethical standards

**Conflict of interest** The authors declare that they have no conflict of interest.

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‘I’ versus ‘death’:

Disentangling effects of self-relevance and negative valence

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**Abstract**

In the literature on attentional capture, it is an open question which factors attract attention automatically. Considering the *relevance hypothesis*, we ask whether relevance allocates attentions as a higher-order factor irrespective of content (e.g., self-relevance versus negative valence) or whether independent factors attract attention. In two experiments we found evidence for a double dissociation of the effects of self-relevant and negative stimuli in attention-related tasks. In Experiment 1, we employed the matching paradigm as introduced by Sui et al. (2012). We replicated the self-prioritization effect (i.e., faster responses to self-associated trials compared to neutral-associated trials) but found no evidence for a negativity-prioritization effect. In Experiment 2, we employed the emotional Stroop task. We replicated the usually observed negativity effect (i.e., slower color-naming latencies for negative stimuli compared to neutral ones) but found no evidence for an analogue effect of self-related stimuli. The reported results reveal insights into the processes underlying effects of self-relevance and negative valence.

Keywords: self, negative valence, relevance, attention

During every waking moment we are flooded by a vast amount of sensory information as a result of the many ongoing events in our environment. Only a minority of this information can be processed consciously. Thus, there is a constant competition amongst the different stimuli in order to be selected for further processing (see Pashler, 1998). Attention is thought to play a central role in biasing the processing of early incoming perceptual information. Still, there is an ongoing debate about which stimulus characteristics (automatically) allocate attention to stimuli – even to task-irrelevant stimuli. In particular, self-relevance and emotional valence, especially negative valence, have been suggested as strong candidates for such a biasing influence. However, it is unclear whether self-relevance and emotional valence are actually biasing attention in the same way (considering both as *relevant* signals) or whether the attention-grabbing effects due to self-relevance and emotional valence are independent. In this article we are going to tackle this important question.

Accordingly, emotional valence per se is a significant non-physical characteristic, which is constantly argued to attract attention (see, e.g., Yiend, 2010, for a review). Anticipating a general functionality to register potential dangers as well as chances in the everyday surrounding, the attention-grabbing potential of highly valent stimuli on task performance has been assessed by different techniques and paradigms (see Brosch, Pourtois, & Sander, 2010, for a review). For example, in a visual search task, task-irrelevant color singletons attracted significantly more attention when the color has been associated previously with either positive or negative valence, as compared to neutral-associated task-irrelevant color singletons (e.g., Anderson, 2015; Wentura, Müller, & Rothermund, 2014). Furthermore, in the emotional Stroop task, the performance on naming the ink color of written words was impeded when the word was emotionally valent as compared to performance on neutral words (e.g., Frings, Englert, Wentura, & Bermeitinger, 2010; see Bertels, Kolinsky, Pietrons, & Morais, 2011, for evidence with an auditory variant of the emotional Stroop task; see Kahan

& Hely, 2008, for evidence of the emotional Stroop effect independent of word frequency). As a result, valence – and negative valence in particular – is discussed to represent a general selection mechanism (Barratt & Bundesen, 2012).

In the literature on the attentional capture due to emotional valence, two hypotheses are controversially discussed: The *threat-detector hypothesis*, assuming that attention is exclusively shifting to highly negative stimuli, and the *relevance hypothesis*, suggesting that attention is shifting to every stimulus which is relevant in any way. The *threat-detector hypothesis* is postulated because several studies failed to find an attention-grabbing effect of positive stimuli while they found an effect of negative stimuli (see e.g., Bertels & Kolinsky, 2015; Kahan & Hely, 2008, for findings in the emotional Stroop task; Mogg & Bradley, 1999; see Smith, Cacioppo, Larsen, & Chartrand, 2003, for a neuro-cognitive study) which was argued in terms of a higher importance of the registration of potential dangers than the registration of potential chances. Those results are interpreted as evidence for negative valence as an autonomous dimension attracting our attention and for a differentiation of positive and negative valence. In contrast, according to the *relevance hypothesis*, not only negative but any kind of relevant stimulus is considered to be able to attract our attention. Hence, personal relevance is postulated to be the crucial attention-grabbing dimension. Evidence for this hypothesis came from studies in which stimuli with (comparably strong) negative or positive valence were contrasted and effects of both valence dimensions were found (see, e.g., Brosch, Sander, Pourtois, & Scherer, 2008; Wentura, et al., 2014; see also Anderson, 2015; Pool, Brosch, Delplanque, & Sander, 2016). Further, stimulating particular needs resulted in an increased attentional bias for associated stimuli (Lavy & van den Hout, 1993) and positive stimuli with no biological or evolutionary relevance were found to attract attention even more than negative stimuli as soon as they were personally relevant (Purkis, Lester, & Field, 2011). In sum, the relevance hypothesis assumes that relevance is a higher-

order dimension and that stimuli might attract attention due to their inherent personal relevance.

In this regard, personal relevance is assumed to be high for threat-related negative stimuli due to the importance of danger sensitivity for survival. In the domain of positively connoted stimuli, things are a bit more complicated. Not any positively connoted stimulus can be regarded as personally relevant (see, e.g., Brosch et al., 2008; Wentura, Rothermund, & Bak, 2000); correspondingly, attentional effects for positive stimuli are on average only modest and divergent. However, self-relevance, that is the association of a particular stimulus to the personal self, is discussed to be an attention-grabbing characteristic. Task-irrelevant, self-related stimuli have been shown to impede performance in different selective-attention paradigms. For example, the participant's face as flankers in a name-identification task resulted in higher reaction times compared to a neutral face (Brédart, Delchambre, & Laureys, 2006), the cuing effect in a visual-search task was larger with the participant's own name than with someone else's name, and in an anti-saccade task participants responded slower when they had to prevent their attention from being captured by their own name than by a neutral name (Alexopoulos, Muller, Ric, & Marendaz, 2012; see also Gray, Ambady, Lowenthal, & Deldin, 2004, for supporting findings with psychophysiological measures). Furthermore, a matching-paradigm was introduced, in which formerly neutral stimuli are associated with the self and in which a robust prioritization of these newly acquired self-associations is observed (Sui, He, & Humphreys, 2012). This self-prioritization effect (SPE) has been replicated several times (see, e.g., Schäfer, Wentura, & Frings, 2015; Sui, Sun, Peng, & Humphreys, 2014), generalized to different labels (Moradi, Sui, Hewstone, & Humphreys, 2015; see Sui et al. 2012, for findings about the SPE's independence of label length, frequency, and familiarity), and extended from visual perception to action (Frings & Wentura, 2014) as well

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as to other sensory modalities (Schäfer, Wesslein, Spence, Wentura, & Frings, in press); finally, neural correlates have been detected (Sui, Liu, Mevorach, & Humphreys, 2013).

In order to find out whether relevance represents a higher-order dimension which is the crucial dimension to attract our attention, we compared the attention-grabbing effects of self-relevant and negative stimuli (as negative valence seems to be the dominant valence category, see, e.g., Kahan & Hely, 2008). Comparable effects of these two categories would speak on behalf of the *relevance hypothesis*. In contrast, when self-relevance and negative valence are autonomous dimensions, then resulting effects should be different in paradigms which are sensitive to either negative valence *or* self-relevance – speaking on behalf of an *independence hypothesis*.

### **The present approach: disentangling self-relevance and negative valence**

We tested self-relevant and highly negative stimuli in two paradigms measuring attentional shift in different ways. On the one hand, we used the matching paradigm as introduced by Sui and her colleagues (2012) in which the essential factor (self-relevance and negative valence) was varied on the task-relevant dimension so that prioritization effects could be assessed (Experiment 1). On the other hand, we used the emotional Stroop paradigm in which the essential factor was varied on the task-irrelevant dimension so that interference effects could be assessed (Experiment 2).

The matching paradigm is typically used to measure effects of self-relevance. In detail, geometric forms are associated either with the self, a familiar other, or a neutral instance and participants are instructed to learn these associations (e.g., “Mary [i.e., the participant’s best friend] is a circle. You are a triangle. And a stranger is represented by a square.”). In a matching task in which participants have to categorize stimulus-label combinations as matching or non-matching according to the learned associations,

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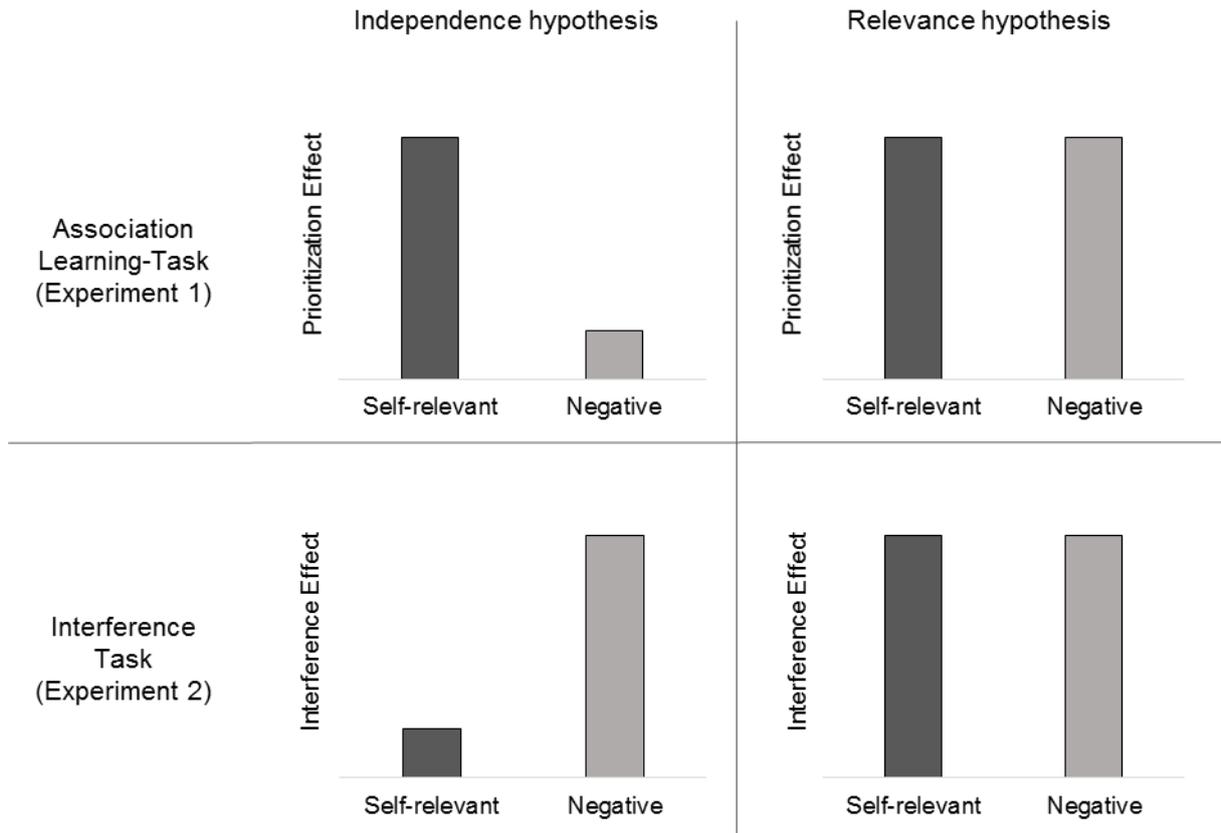
performance on matching trials with the self-relevant label is significantly better than performance on matching trials with one of the two non-self-relevant labels (see, e.g., Sui et al., 2014; Schäfer et al., 2015). The repeatedly found SPE is discussed in terms of a learning advantage for the self-relevant association. In this context, redundancy gains (i.e., response times on trials with two redundant stimuli compared to response times on a single-stimulus baseline in trials with one stimulus) were assessed for self-relevant and non-self-relevant shapes. The results revealed a higher redundancy gain for self-relevant shapes than for non-self-relevant shapes, indicating enhanced integration of self-relevant stimuli (Sui, Yankouskaya, & Humphreys, 2015). Besides, the prioritization of self-relevant associations vanished when the learning of other-relevant associations was selectively enhanced (Fuentes, Sui, Estévez, & Humphreys, 2015). Hence, according to the *relevance hypothesis*, when relevance represents the crucial attention-allocating dimension, in Experiment 1 the effect of negative valence should be equal to the typically measured effect of self-relevance. But according to the *independence hypothesis*, when self-relevance and negative valence are autonomous dimensions and the effect of self-relevance represents a learning advantage whereas the effect of negative valence represents an automatic attentional shift, then there should be an effect of self-relevance but no effect of negative valence in Experiment 1.

In contrast, the emotional Stroop paradigm is considered to be sensitive to effects of negative valence. Here, while participants are instructed to name the color of negative and neutral words, responses on negative words are slowed down compared to responses on neutral words (see Williams, Mathews, & MacLeod, 1996, for a review; Phaf & Kan, 2007, for a meta-analysis). While the emotional Stroop effect has been assumed previously to represent a generic slow down, comparable to a freezing response, meanwhile the effect of (task irrelevant) negative valence is discussed to depict a long-lasting attentional effect and a negative delay in that attentional disengagement takes longer from negative stimuli than from

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neutral stimuli (Bertels & Kolinsky, 2015; Estes & Verges, 2008). Thus, when valence is irrelevant to the task, negative valence attracts attention and impedes the relevant response. Hence, we hypothesize an effect of negative stimuli in Experiment 2. The *relevance hypothesis* would postulate an effect of self-relevance as well. Contrary to that, when the effect of self-relevance represents a learning advantage and no automatic attentional shift, then the *independence hypothesis* would postulate an effect of negative valence and no effect of self-relevance in Experiment 2. Figure 1 illustrates the hypothesized data patterns for self-relevant and negative stimuli in Experiments 1 and 2 according to both, the relevance and the independence hypothesis.

In both experiments, we added highly positive stimuli as a third condition to test for the specificity of effects of self-relevant and negative stimuli. However, these stimuli are not necessarily tangent to our hypotheses. As briefly sketched above, not any positive stimulus can be considered personally relevant (see, e.g., Brosch et al., 2008; Wentura et al., 2000). Although a recent meta-analysis (Pool et al., 2016) indicates evidence for attentional biases for positive compared to neutral stimuli, effects were, modest, especially for positive items employed in the emotional Stroop task and which were not relevant to specific concerns.



**Figure 1.** According to the two hypotheses, the predicted effects of self-relevant and negative stimuli in an association-learning task (Experiment 1) and in an interference task (Experiment 2).

### Experiment 1

In order to contrast the effects of self-relevance and negative valence on association learning, we adapted the matching paradigm and assigned four neutral geometric forms to either a self-relevant, a highly negative, a highly positive, or a neutral stimulus. The prioritization effects of main interest were measured as the difference between performance in the self-relevant or negative condition compared to performance in a neutral condition.

### Method

**Participants.** Forty students from the University of Trier (34 female) took part in the experiment receiving course credit. Median age was 21 years (ranging from 18 to 39) and they all had normal or corrected-to-normal vision.

The SPE with visual stimuli (as the difference between the mean RT in self-relevant matching trials and the mean RT in non-self-relevant matching trials) was rather large in previous studies ( $d_z > 0.65$  in Schäfer et al., 2015; Sui et al., 2012). A sample of  $N = 40$  allows to test for effects of  $d_z = .60$  with a power of  $1 - \beta = .96$  (two-tailed,  $\alpha = .05$ ; G\*Power 3.1.3, Faul, Erdfelder, Lang, & Buchner, 2007).

**Design.** Experiment 1 comprised a 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape: *self-associated* vs. *negative-associated* vs. *positive-associated* vs. *neutral-associated*) within-participants design. The assignment of the shapes to the labels was balanced across participants following a Latin-square design.

**Material and Apparatus.** The experiment was conducted using standard PCs with TFT monitors that had a display resolution of  $1,280 \times 1,024$  pixels, standard German QWERTZ keyboards and by using E-Prime 2.0 software. The geometric shapes were a square, a circle, a triangle, and a rectangle and were associated either with the German word *Ich* [I] as the self-relevant label, or with one of ten words with distinct valence in the negative, positive, and neutral condition. Balanced across participants a negative, a positive, and a neutral label was chosen out of the following words, *Folter* [torture], *Mord* [murder], *Krieg* [war], *Henker* [executioner], *Unfall* [accident], *Gewalt* [violence], *Gift* [poison], *Pest* [plague], *Sadist* [sadist], and *Horror* [horror] in the negative condition; *Musik* [music], *Blume* [flower], *Leben* [life], *Liebe* [love], *Meer* [sea], *Urlaub* [holiday], *Natur* [nature], *Sommer* [summer], *Freund* [friend], and *Lachen* [laugh] in the positive condition; and *Wand* [wall], *Klinke* [handle], *Balken* [beam], *Hose* [trouser], *Brett* [board], *Tisch* [table], *Herd* [stove], *Teller* [plate], *Lampe* [lamp], and *Boden* [floor] in the neutral condition. The labels in the negative, positive, and neutral condition were selected and classified according to a priori based valence rating (Wentura, 1998) which revealed a mean rating of  $-2.56$  ( $SD = 0.22$ ) for the negative words,  $2.60$  ( $SD = 0.14$ ) for the positive words, and  $0.05$  ( $SD = 0.11$ ) for the

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neutral words on a scale from -3 (negative) to +3 (positive). Additionally, a mean valence rating subsequent to the experiment (-3 = negative, +3 = positive) was -2.15 (SD = 1.3) for the negative words, 2.08 (SD = 1.3) for the positive words, and -0.03 (SD = 0.8) for the neutral words.

All stimuli were presented in white on black background. The labels were presented in Courier New, with a viewing distance of about 60 cm resulting in a visual angle of about 0.57°. The geometric shapes, the labels, and a fixation cross were presented from the center of the computer screen, subtending 4.3° × 4.3° visual angle for the geometric shapes (except for the rectangle which was 4.3° visual angle high and 8.6° wide).

**Procedure.** Participants were tested individually in sound-proofed chambers. Task instructions were given on the screen and summarized by the experimenter. The experiment started with a learning phase, in which the to-be-learned assignments were shown on the display for 60 seconds in written form. For a particular participant the instruction might read: “I am a triangle. Poison is a circle. Music is a square. And trouser is a rectangle.” Participants were instructed to place the index finger of the left hand on the S-key (non-matching response) and the index finger of the right hand on the L-key (matching response).

After the learning phase, the matching task began. Here, each trial started with a 500 ms presentation of a black screen, followed by a fixation cross for 500 ms. Then a pairing of one of the labels and one of the geometric shapes was presented for 100 ms, followed by a black screen until the participant responded or 1,500 ms had elapsed. Participants’ task was to judge whether the displayed label-shape pairing corresponded to one of the initially learned assignments or not. One experimental session consisted of a short practice block with 24 trials (in which feedback was given on the screen) and an experimental block with 240 trials (without feedback). In the experimental phase, each geometric shape was presented in 60

trials. Half of the trials depicted matching and half of them non-matching assignments. The same proportions were realized in the practice phase. Trials were presented in random order.

## Results

Only correct responses with RTs above 200 ms and below 3 interquartile ranges above the third quartile of the individual RT distribution (Tukey, 1977) were used for the RT analysis. Averaged across participants, 83.4% of the trials were selected for RT analysis, 16.0% of the trials were excluded because of erroneous responses, 0.6% due to the RT outlier criteria. Mean RTs and error rates are shown in Table 1.

**Table 1.** Mean RTs (in milliseconds) and error rates (in %) as a function of matching condition (*matching* vs. *non-matching*) and shape association (*self* vs. *positive* vs. *negative* vs. *neutral*). Standard deviations in brackets.

		<i>Matching Condition</i>			
		<i>Matching</i>		<i>Non-matching</i>	
		<i>RTs</i>	<i>Error Rates</i>	<i>RTs</i>	<i>Error Rates</i>
<i>Shape Association</i>	<i>Self</i>	605	1.6 (2.2)	726	2.0 (1.8)
	<i>Negative</i>	666	2.0 (2.1)	725	2.2 (1.7)
	<i>Positive</i>	672	1.9 (1.8)	734	2.4 (1.9)
	<i>Neutral</i>	675	2.2 (1.9)	732	1.8 (1.5)

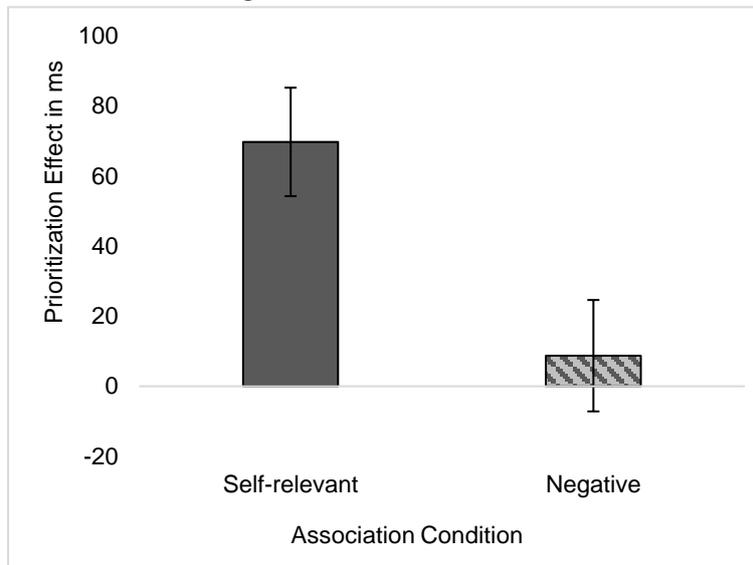
**Reaction times.** In a 2 (matching condition: *matching* vs. *non-matching*)  $\times$  4 (shape association: *self* vs. *negative* vs. *positive* vs. *neutral*) repeated-measures MANOVA with mean RTs as the dependent variable, both main effects were significant,  $F(1,39) = 114.32, p < .001, \eta_p^2 = .75$ , for matching condition and  $F(3,37) = 4.91, p = .006, \eta_p^2 = .29$ , for shape association, indicating faster responses in matching trials and a difference in the RT data due to the shape association. The interaction was also significant,  $F(3,37) = 7.16, p < .001, \eta_p^2 = .37$ ,

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showing that the effect of the shape association was different in matching than in non-matching trials.

Following the significant interaction of matching condition and shape association and in accordance to Sui et al. (2012), prioritization was analyzed in the matching trials. That is, so far, the SPE is defined as the difference between the mean RT in matching trials with the self-associated label and the mean RT in matching trials with a neutral label. Consequently, prioritization effects were assessed by the difference between mean RTs in the neutral-associated trials and mean RTs in the self- or negative-associated trials. These comparisons corresponded to simple contrasts in a one-factorial MANOVA for repeated measures (shape association: *self* vs. *negative* vs. *positive* vs. *neutral*) with RTs of matching trials as the dependent variable and the neutral condition as the reference category. Besides the fact that the main effect was significant,  $F(3, 37) = 7.87, p < .001, \eta_p^2 = .39$ , the prioritization effect in the self-associated condition (indicated by a simple contrast) was significant,  $F(1, 39) = 20.30, p < .001, \eta_p^2 = .34$ , whereas the corresponding prioritization effect in the negative-associated condition was not significant,  $F < 1$ . This suggests that responses were significantly faster in self-associated trials compared to neutral-associated trials but not in negative-associated trials (see Figure 2). For the sake of completeness, note that the simple contrast for positive items was not significant either,  $F < 1$ .

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**Figure 2.** Prioritization effects in RTs for the particular shape conditions. The error bars indicate the standard errors of the means.

Finally, mean RTs for self-relevant items were significantly faster than mean RTs for negative items,  $t(39) = -3.91$ ,  $p < .001$ ,  $d_z = .62$ . Note that this result is equivalent to the test whether the mean prioritization score for self (i.e.,  $RT_{\text{neutral}}$  minus  $RT_{\text{self}}$ ) is larger than the mean prioritization score for negative items (i.e.,  $RT_{\text{neutral}}$  minus  $RT_{\text{negative}}$ ; see Figure 2).

**Sensitivity measures.** Accuracy rates were analyzed computing detection-sensitivity indices ( $d'$ ) for each shape condition. Correct responses in matching trials were considered hits, whereas erroneous responses in non-matching trials were considered false alarms. We followed the log-linear approach to account for cases with 100 % hits or 0 % false alarms (see Hautus, 1995; Stanislaw & Todorov, 1999) by computing the  $d'$  indices. A one-factorial repeated-measures MANOVA with  $d'$  as the dependent variable and the within-participant factor shape (*self-associated* vs. *negative-associated* vs. *positive-associated* vs. *neutral-associated*) revealed a significant main effect,  $F(3, 37) = 3.07$ ,  $p = .040$ ,  $\eta_p^2 = .20$ , indicating that sensitivity varied according to the shape. Moreover, comparable to the analysis in the RT data, significant prioritization effects (i.e., simple contrasts with the reference category neutral) were only found for the self-associated condition,  $F(1, 39) = 6.39$ ,  $p = .016$ ,  $\eta_p^2 = .14$ , suggesting a higher sensitivity in self-associated trials compared to neutral-

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associated trials. As for the RTs, the prioritization effects in the negative-associated condition as well as in the positive condition were not significant,  $F_s < 1$ .

Finally, mean  $d'$  for the self-relevant condition was significantly larger than mean  $d'$  for the negative condition,  $t(39) = 2.34, p = .024, d_z = .37$ , indicating even in  $d'$  a significantly larger prioritization effect in the self-relevant condition than in the negative condition.

## Discussion

The data of Experiment 1 revealed a prioritization effect of self-relevant associations (as in previous studies) that was significantly different from the (non-significant) prioritization effect of negative associations. Thus, when assessing effects on association learning, the effect of self-relevance was different from the effects of negative valence – speaking against a higher-order relevance dimension and on behalf of the *independence hypothesis*.

## Experiment 2

In Experiment 2, effects of self-relevant and negative stimuli were compared in an interference task. Therefore, self-relevant, negative, positive, and neutral words were presented in a color-naming task (emotional Stroop task) and interference was measured as the difference between performance in the self-relevant or negative condition compared to performance in a neutral condition. Thus, Experiment 2 was conducted in order to assess the opposite effects of the given stimuli in the sense of a double dissociation of the effects of self-relevance and negative valence.

## Method

**Participants.** Ninety students from the University of Trier (63 female) took part in the experiment receiving course credit. Median age was 22 years (ranging from 18 to 30). All participants had normal or corrected-to-normal vision. The data of a further participant were discarded due a red-green deficiency.

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Emotional Stroop effects were modest in previous studies ( $d_z > 0.32 - 0.39$  in Frings et al., 2010). A sample of  $N = 90$  allows to test for effects of  $d_z = .30$  with a power of  $1 - \beta = .80$  ( $\alpha = .05$ ; G\*Power 3.1.3, Faul et al., 2007).

**Design.** The experiment comprised a one-factorial, repeated-measures design with the within-participant factor word category (*self-relevant vs. negative vs. positive vs. neutral nouns vs. neutral pronouns*).

**Material and apparatus.** The experiment was conducted using standard PCs with TFT monitors that had a display resolution of  $1,280 \times 1,024$  pixels, standard German QWERTZ keyboards and by using E-Prime 2.0 software. The labels were mainly selected from the same word list as in Experiment 1 (Wentura, 1998) and self-relevant and neutral pronouns were added. In detail, the German words *Mast* [pole], *Hose* [trousers], *Herd* [stove] and *Brett* [board] were used in the neutral-nouns condition; *Gift* [poison], *Mord* [murder], *Krieg* [war], and *Tod* [death] in the negative condition; *Blume* [flower], *Leben* [life], *Liebe* [love], and *Glück* [fortune] in the positive condition; *Ich* [I], *Mein* [my], *Mich* [me], and *Mir* [mine] in the self-relevant condition; and *Er* [he], *Sie* [she], *Es* [it], and *Ihr* [you (plural)] in the neutral-pronouns condition.<sup>1</sup> An a priori valence rating (Wentura, 1998) revealed a mean valence rating of 0.04 ( $SD = 0.05$ ) in the neutral condition, -2.67 ( $SD = 0.23$ ) in the negative condition, and 2.55 ( $SD = 0.18$ ) in the positive condition.

The labels were written in Courier New and were presented in the middle of the screen on black background. Moreover, they were presented in yellow (RGB values: 250, 255, 45), green (130, 230, 70), blue (10, 50, 250), and purple (170, 50, 250). For the duration of the

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<sup>1</sup> Note that in the emotional Stroop paradigm the number of labels per category should be equal, resulting in four words per condition due to the small number of appropriate self-relevant labels. The neutral-pronoun condition was added as a further control condition to account for the fact that negative and positive words were nouns whereas self-relevant words were pronouns.

experiment, the viewing distance of about 60 cm was controlled with chin rests and resulted in a visual angle of about  $0.95^\circ$  for the labels.

**Procedure.** Participants were tested individually in sound-proofed chambers. They were instructed (on the screen and summarized by the experimenter in the beginning of the experiment) to classify the color of each presented word via keyboard: yellow with the V-key (index finger of the left hand), green with the N-key (index finger of the right hand), blue with the F-key (middle finger of the left hand), and purple with the J-key (middle finger of the right hand).

The experiment started with a practice phase, in which numerals (the German words *Eins* [one], *Zwei* [two], *Drei* [three], *Vier* [four], *Fünf* [five], *Sechs* [six], *Sieben* [seven], and *Acht* [eight]) were presented in the given colors and participants were instructed to react as fast and accurately as possible with the given keys. Each numeral was presented once in each color, resulting in 32 practice trials. In the practice phase, feedback was given whether the participant responded correctly. After the practice phase, the experimental phase started. Here, the given labels in the five word-category conditions were presented in the given colors. The word categories (neutral nouns, negative nouns, positive nouns, self-relevant pronouns, neutral pronouns) were presented blockwise in order to control for across-trials effects (see Frings et al., 2010; McKenna & Sharma, 2004, for the impact of fast and slow effects in the emotional Stroop task) and there were 20-sec breaks between the blocks. In each word-category block, each of the four labels was presented once in each of the four colors, resulting in 16 trials. The five word-category blocks were presented three times, resulting in 240 trials in the experimental phase.

Each trial, in the practice and in the learning phase, started with a fixation cross for 500 ms after which the label was presented until the participant responded, followed by an inter-stimulus interval of 30 ms. After a 20-sec break between the word-category blocks, a

fixation cross was presented for 1,500 ms before the next block started. Within the blocks, trials were presented in random order.

## Results

Only correct responses with RTs above 200 ms and below 3 interquartile ranges above the third quartile of the individual RT distribution (Tukey, 1977) were used for the RT analysis. Averaged across participants, 93.0 % of the trials were selected for RT analysis, 6.0 % of the trials were excluded because of erroneous responses and 1.0 % due to the RT outlier criteria. Note that neither the mean RTs nor the mean error rates in the two neutral conditions (i.e., the neutral-noun and the neutral-pronoun condition) differed significantly (RTs:  $M = 591$  [ $SD = 86.5$ ] for nouns and  $M = 589$  [ $SD = 81.9$ ] for pronouns; error rates:  $M = 1.57$  [ $SD = 2.32$ ] for nouns and  $M = 1.44$  [ $SD = 2.20$ ] for pronouns), both  $t_s < 1.13$ , both  $p_s > .262$ . Hence, the two conditions were merged to a single neutral control condition. Mean RTs and error rates in the resulting conditions are shown in Table 2.

**Table 2.** Mean RTs (in milliseconds) and error rates (in %) as a function of word category (self-relevant vs. negative vs. positive vs. neutral control condition). Standard deviations in brackets.

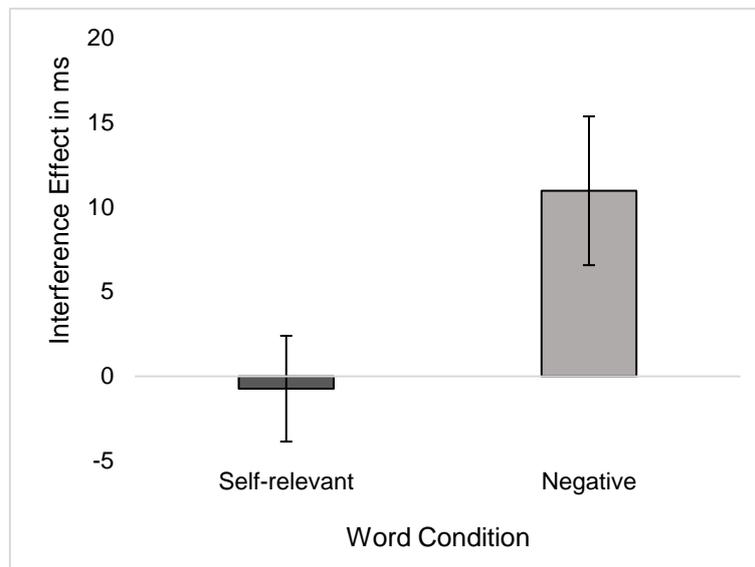
		<i>RTs</i>	<i>Error Rates</i>
<i>Word Category</i>	<i>Self-relevant</i>	589 (78)	1.6 (2.1)
	<i>Negative</i>	601 (82)	1.5 (2.1)
	<i>Positive</i>	591 (77)	1.4 (2.2)
	<i>Neutral</i>	590 (81)	1.5 (2.2)

**Reaction times.** In a one-factorial (word category: *self-relevant* vs. *negative* vs. *positive* vs. *neutral*) repeated-measures MANOVA with mean RTs as the dependent variable,

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the main effect of word condition just missed the conventional criterion of significance,  $F(3, 87) = 2.63, p = .055, \eta_p^2 = .08$ .

Interference effects were assessed by comparing mean RTs in the neutral condition and mean RTs in the negative or self-relevant condition, respectively (which were represented by simple contrast in the MANOVA). Only the interference effect in the negative condition was significant,  $F(1, 89) = 6.22, p = .014, \eta_p^2 = .07$ , representing a typical emotional Stroop effect. There was no such interference effect in the self-relevant condition,  $F < 1$  (see Figure 3). For the sake of completeness, note that the simple contrast positive versus neutral was non-significant either,  $F < 1$ .



**Figure 3.** Interference effects in RTs for the particular word conditions. The error bars indicate the standard errors of the means.

Finally, mean RTs in the self-relevant and in the negative condition were significantly different,  $t(89) = 2.58, p = .012, d_z = .27$ , indicating a significantly larger interference effect in the negative condition than in the self-relevant condition.

**Error rates.** A one-factorial (word category: *self-relevant* vs. *negative* vs. *positive* vs. *neutral*) repeated-measures MANOVA with error rates as the dependent variable revealed a non-significant main effect,  $F(3, 87) = 1.04, p = .378, \eta_p^2 = .04$ , indicating that there was no

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effect of word condition on error rates. Accordingly, there was no evidence for any speed-accuracy trade-off.

### **Discussion**

The combination of self-relevant, negative, positive, and neutral stimuli in an interference task confirmed the hypothesis of an effect of negative stimuli, indicating the typical emotional Stroop effect. Above that, there was no indication for an effect of self-relevant stimuli and there was a significant difference between the interference due to negative stimuli compared to the interference due to self-relevant stimuli. Consequently, in addition to the results of Experiment 1, the data pattern observed in the emotional Stroop paradigm speaks against the *relevance hypothesis* and in favor of the *independence hypothesis*.

Note that there were two methodological concerns in Experiment 2. First, it has been shown repeatedly that lexical characteristics of the used word material play an important role in the emotional Stroop task. Accordingly, response time differences due to negative valence were no longer significant after covarying out the effects of lexical characteristics (Larsen, Mercer, & Balota, 2006). In particular, word frequency needs to be matched for the used stimuli and should be as low as possible (Kahan & Hely, 2008). Consequently, the word material in Experiment 2 had to be chosen based on these findings and the participants' names or the personal pronoun "I" could not be used. Second, so far, empirical evidence is inconsistent about whether self-relevant stimuli cause an effect in a color-naming task or not. For example, Harris and Pashler (2004) found slowed responses in trials with the participants' names, but this effect vanished when the name was presented with high proportion, that is in half of the trials. Further, personally significant items like the participants' first names, family names, or mothers' names led to slower response times when presented centrally (Gronau, Cohen, & Ben-Shakhar, 2003), but note that these items per se were more familiar compared

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to the used neutral words (e.g., unknown first or family names) and, as mentioned above, this might have triggered the effect. In another study, under evaluative conditions (explicitly manipulating the participants' self-awareness) *faster* responses were found in trials with a self-relevant label but, remarkably, the used word material was not only self-relevant but also negative (words such as “disliked” or “impotent”; Geller & Shaver, 1976). Thus, we did not predict an effect of self-relevant stimuli in the emotional Stroop task with the used material.

### General Discussion

The aim of our experiments was to figure out whether relevance – as a superordinate category irrespective of its content – biases the allocation of attention. In particular, we asked whether the repeatedly found attention-grabbing effects of negative valence on the one hand and self-relevance on the other hand reflect actually the same process or two different processes. Two hypothesis were contrasted, the *relevance hypothesis*, according to which the effects of negative valence and self-relevance should be equal, and the *independence hypothesis*, postulating independent effects of negative valence and self-relevance. In order to disentangle effects of self-relevance and negative valence, the two effects were compared in one paradigm assessing attention biases to the *task-relevant* dimension (matching paradigm) and in another paradigm assessing attention biases to the *task-irrelevant* dimension (emotional Stroop paradigm). We found an effect of self-relevance in the matching paradigm and an effect of negativity in the emotional Stroop paradigm but not vice versa. Thus, the resulting data patterns of both experiments were unequivocally in accordance with the predictions of the *independence hypothesis*, suggesting different processes underlying the effects of negative valence and self-relevance.

Considering that the measured effects of negative valence and self-relevance differed and, moreover, were reversed in the two paradigms, one might conclude that negative valence attracts attention and represents a general selection mechanism guiding our attention (without

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disentangling attention engagement and disengagement at this point; Clarke, MacLeod, & Guastella, 2013; Fox, Russo, Bowles, & Dutton, 2001; Yiend, 2010), whereas self-relevance boosts the learning of arbitrary associations (Fuentes, Sui, Estévez, & Humphreys, 2015; Sui, Yankouskaya, & Humphreys, 2015; see also Cunningham, Turk, Macdonald, & Macrae, 2008; Englert & Wentura, 2016). Hence, when negative and self-relevant stimuli are combined as distracting characteristics on a task-irrelevant dimension, as it is the case in the emotional Stroop paradigm, then negative stimuli cause the dominant effect. That is, negative valence automatically attracts attention and therefore impedes the relevant response whereas self-relevance does not. Against that, when negative and self-relevant stimuli represent task-relevant characteristics in a matching task, then only self-relevant stimuli cause a prioritization indicated by faster and more accurate matching responses.

As an aside, we did not find an effect of positive valence in both experiments. As mentioned above, attentional effects for positive stimuli do not necessarily occur in the emotional Stroop paradigm (see, e.g., Bertels & Kolinsky, 2015). In the matching paradigm, effects of positive valence due to associations with high reward were assessed. Although similar effects of self-relevance and reward were found, several studies pointed out a difference between these effects (see, e.g., Sui & Humphreys, 2014; Sui, Yankouskaya, & Humphreys, 2015). Importantly, it does not seem implausible that positive valence would generally cause an effect in the matching task (and the same holds true for negative valence), potentially at least due to attentional asymmetries in the paradigm when one highly valent stimulus is combined with two neutral stimuli (see Schäfer, Wentura, & Frings, 2016, for the indication of attentional asymmetries in the matching paradigm). Still, to the best of our knowledge, positive emotional valence and self-relevance have not been combined yet in a matching task and a dominant effect of a self-relevant stimulus beyond a positive or a negative stimulus again emphasizes different underlying processes.

On a more general note, our results might reflect a distinction that may have sometimes been overlooked when attention-grabbing effects of self-relevance or negative valence were analyzed. A coarse separation of attention processes is to separate focused attention on the task at hand versus attention towards the environment. The first one (focused attention on the task at hand) is often discussed as selective attention, that is, a process of separating task-relevant and task-irrelevant stimuli. Selective attention is determined by current action goals (e.g., Allport, 1987; Folk, Remington, & Johnston, 1992; Mast & Frings, 2014; Neumann, 1990; Frings & Wentura, 2006). In contrast, the second attention process (attention towards the environment) is usually discussed as screening the environment for possible dangers or chances irrespective of the current action goals, potentially in service of survival (Pratto & John, 1991; Öhman, Flykt, & Esteves, 2001; Öhman & Mineka, 2001; Wentura et al., 2000).

Possibly, effects of self-relevance and emotional valence impact differently upon attention in dependence of these two functions of attention. Going back to our current experiments, in the matching paradigm we see prioritized processing of self-relevant stimuli (but not negative stimuli) in a context where these stimuli are part of the current action goals. In the emotional Stroop task, on the contrary, the content of the words cannot be related to the current action goal of naming the color.<sup>2</sup> However, if one looks at previous research it might not always be easy to define in a particular paradigm whether a self-relevant or negative stimulus is part of the environment or part of the current action goal. For instance, in the negative priming task (e.g., Neill, 1977; Tipper, 1985), participants ignore a distractor while responding to a target and if the distractor repeats as the next target, performance is usually

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<sup>2</sup> Note the contrast to the standard Stroop task (i.e., naming of the color of color words) where the word content is never task-relevant in a narrow sense but it is clearly related to the current action goal of naming colors. Hence, the emotional Stroop task and the standard Stroop task are discussed as different paradigms (Algom, Chajut, & Lev, 2004).

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worse (see Frings, Schneider, & Fox, 2015, for a recent review). Yet, Frings (2006) found no negative-priming effects for self-relevant stimuli, whereas negative stimuli typically elicited normal negative-priming effects in healthy participants (Frings, Wentura, & Holtz, 2007; Wentura, 1999). Yet, is a distractor to which one has not to respond part of the environment (surrounding the target stimulus) or is it in fact related to the action goal (because each distractor stimulus is a possible target of a different trial)? Although beyond the scope of the present article, we think that many published effects of self-relevance or emotional valence should be re-evaluated with this question in mind. It might be that in many paradigms it could not be clearly stated whether the attention-grabbing potential of a stimulus is due to its relatedness to current action goals (and hence the effect has to be discussed in light of the selective-attention function) or whether the attention-grabbing potential of a stimulus is due to its relatedness to survival (and hence the effect has to be discussed in light of the vigilance function of attention). Thus, it can be an exciting road for future research to further pursue this idea of an interaction between different stimulus dimensions with different attentional functions.

In sum, our results support the assumption of two independent processes triggering the effects of negative valence on the one hand and self-relevance on the other hand. Moreover, the chosen paradigms might indicate that negative valence represents an endogenous, bottom-up selection mechanism, allocating our attention automatically even to irrelevant features of our visual field, whereas self-relevance does not involuntarily capture attention but rather represents a top-down effect which influences learning of relevant input.

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## Disentangling self-relevance and negative valence

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## 5. General Discussion

As a whole, the studies enclosed in this dissertation underpin the adequacy of the MP as a tool to assess effects of self-relevance independent of stimulus familiarity, provide a further understanding of the relevant cognitive aspects of self-representations and, moreover, yield a specification of the general effect of self-relevance on stimulus processing.

Specifically, the evidence reported in the first article (chapter 3.1.) points out that responses in the matching task can be influenced by general salience-triggered processes unrelated to the effects of self-relevance. Nevertheless, a genuine self-related process was identified which was independent of salience effects, suggesting that the SPE in the matching task goes beyond this salience effect and is more than just the recoding of perceptually salient content. Furthermore, six experiments in three of the articles enclosed (chapter 3.2., 3.3., and 3.4.) support the assumption that complex, abstract content rather than specific perceptual features is included in the self-representation. According to that, on the one hand, associating feature conjunctions with the self did not reveal any evidence of separate, binary feature-self bindings, emphasizing the functionality of self-relevance, and, on the other hand, the SPE was repeatedly shown to be independent of perceptual aspects of the associated stimulus either varying features or varying the sensory modality, indicating that self-prioritization represents a more general tendency which influences stimulus processing. Above that, the results from the fifth article (chapter 3.5.) indicate a dissociation of the effects of self-relevance and negative valence (as a dominant, attention-guiding valence category), contradicting the assumption of an attention-guiding effect of relevance per se. Besides, the observation of an effect of self-relevance on association learning, in the absence of a distracting effect, suggests that self-relevance does not represent a general selection mechanism, but rather boosts the learning of stimulus associations.

The implications of the whole of results reported within this dissertation mainly refer to an understanding of the self as a core self-representation and to an understanding of its generation. Combining the results and thus viewing the self as a network of stimulus associations, reveals a comprehensive picture of the self as a flexible, adaptive structure of strongly related, different aspects and concepts. From a wider perspective, this understanding goes together with current, partly philosophical understandings of the self. For example, the description of the self as a flexible association network coincides with the meanwhile established conception of the 'minimal self' as a basic, immediate instance which adapts consist-

ently to the environment (Gallagher, 2000). Comparably, the robust effect of self-prioritization and the assumption of a general self-prioritization mechanism (indicated by the evidence of a SPE in different sensory modalities) matches the conception of the 'minimal self' as an embodied concept which is based on the perceptual experience of environmental information independent of linguistic or conceptual knowledge (Gallagher, 2000). Hence, the described effects of self-relevance are in line with previous conceptions of the self and contribute substantially to an even more concrete understanding of the self, adding the assumption of an association network. That is, considering that the self-representation is basic, embodied, and adaptive and that self-associations are generated fast and functionally, a *specific, complex network of associations between different concepts forming the personal self-representation* can be postulated.

According to the specification of the general effects of self-relevance on stimulus processing, that is according to the question about how self-relevance influences our cognitions in everyday life (and how it does not!), the differentiation of self-effects from effects of valence point out a rather specific influence of self-relevance. However, one has to bear in mind that this interpretation so far bases on no more than two studies. Nevertheless, the absence of an effect of self-associations when task-irrelevant actually indicates that self-relevance does not represent a general selection mechanism guiding attention automatically. Thus, self-relevance should *not* be understood as one of few factors which automatically control attention allocation and it should *not* be put on the same level with attention-guiding factors like valence. Note that this further implies that the earlier found attention-guiding effects of self-relevant material, like for example the distracting effect of the own name in a flanker task (Frings, 2006), or the attention-capturing effect of the own name in a cuing paradigm (Alexopoulos et al., 2012), are likely not to-be-attributed to the self-relevance of the material, but to its familiarity. Still, self-relevance was found to cause a dominant effect when used to manipulate the learning and classification of arbitrary associations. This finding of a dominant effect on association classification indicates a self-effect due to a learning advantage for self-associated content, coinciding with former mentioned results speaking against a perceptual bias due to self-relevance (Stein et al., 2016), but in favor of an integration advantage for self-relevant material (Fuentes et al., 2015; Sui & Humphreys, 2015). And again, the conclusion that *self-relevance improves association learning* underpins the importance of associations for the self-representation.

In sum, to give an outlook for further research, the conception of the self-representation as a specific, complex network of associations between different concepts and

the conclusion that self-relevance improves association learning rather than guiding attention, provides several points of contact to other research fields. For instance, the adaptability of the self-representation raises the question of the development of a personal self-representation over the lifespan. On the one hand, especially regarding the non-perceptual, higher-order component of self-prioritization, further studies should assess self-prioritization in children. General cognitive capacities should only play a minor role in self-prioritization (considering the basic, language independent nature of the core self-representation, see Gallagher, 2000) rather should the existence of self-consciousness or a self-concept be the driving source. Note that, fortunately, the MP seems to be easily adapted for testing young children. On the other hand, a change of self-prioritization at an older age could also be interesting, in particular a dependence of the SPE on lifespan developmental functions like stabilizing and immunizing processes. Considering a positivity bias in elderly people (for a review of the bias effect, see e.g., Mezulis, Abramson, Hyde, & Hankin, 2004), it is plausible to ask whether at least the integration of negative-connoted stimuli declines over the lifespan. Above that, the finding of stable self-prioritization in elderly people with low working memory capacities (at least when selected due to this criterion) but a consolidated self-concept, in combination with the finding of no self-prioritization in very young children with low working memory capacities and no consolidated self-concept (when controlled for that), would suggest a dependence of self-prioritization on the existence of a self-concept rather than a dependence on general cognitive capacities.

Moreover, the assessment of the integration of negative-connoted stimuli could be the basis for another important area of research, dealing with the integration and also the disintegration of stimuli. Regarding the flexibility and adaptability of the self-representation, one could assume two immunizing processes: the *non-integration* of highly negative stimuli into the self-network as well as the *disintegration* of previously integrated stimuli as soon as they become adverse. Such questions could be easily handled by adapting the MP and either associating, for example, loss-connoted stimuli with the self and measuring the SPE, or by inducing a subsequent negativity of stimuli which had previously been associated with the self. The finding of such immunizing processes would further certify the functionality of self-representations and the resulting self-prioritization, in that self-prioritization adapts to situations and contexts, striving for a self-serving stimulus processing.

Additionally, the conceptualization of the self-representation as a 'minimal self', which is described to depend essentially on the sense of self-ownership (i.e., the sense that something is the person's body/part of the person's body) and self-agency (i.e., the sense of

being the initiator for an action; see e.g., Gallagher, 2000), also emphasizes the influence of all sensory feedback for the self-representation. This description of the self corresponds with the finding that self-prioritization influences stimulus processing in sensory modalities other than vision. Following research could assess influences of self-relevance *across* sensory modalities. Since the mentioned results in chapter 3.1. about the SPE's independence of the sensory modality are explained by a mediation due to the semantic concept of the stimuli, a prioritization of a self-associated stimulus across the sensory modalities remains to be shown. Considering a multisensory influence on self-prioritization, it is also noteworthy that specific brain areas are associated with both multisensory integration and the processing of social salience, like the left posterior superior temporal sulcus (see, e.g., Senkowski, Schneider, Foxe, & Engel, 2008; Sui, et al., 2013). Thus, future research should, for example, test the prioritization of multisensory stimuli. Here, one could hypothesize to observe a benefit for self-prioritization with bimodal stimuli compared to the self-prioritization with unimodal stimuli. Together with the evidence for a learning advantage of a particular stimulus in one sensory modality when presented with an additive stimulus in another sensory modality (for instance a combination of visual animations and verbal narration, see Mayer, 1997), a bimodal self-prioritization benefit would further support the interpretation of the SPE as a learning advantage. In the context of sensory modality comparison and in the light of the above-mentioned literature on body ownership and boundaries of the self (Gallace & Spence, 2014), the importance of vibrotactile stimulation for self-prioritization should also be assessed in more detail. That is, the benefit caused by additive vibro-tactile information could for example be compared to the benefit caused by additive auditory information.

What is more, further research is necessary to answer the question about variations of and differences in self-prioritization. Studies using the MP continuously revealed a variation of the measured SPE between participants. However, it is still unclear whether this variation of the size of the effect can be explained by inter- or intraindividual differences. As already mentioned in the beginning, there is evidence for a dependence of the own-name effect on working memory capacity (Conway et al., 2001) and on explicit self-esteem (Wentura et al., 2005). Hence, testing whether the variance of the size of the SPE is caused either by individual or by situational differences would help to further clarify the underlying processes triggering the SPE. For instance, a correlation of the SPE with individual, self-related variables like the explicit self-esteem would reinforce a genuine, basal effect of self-relevance, whereas a dependence on situational factors, like the current mood or context, suggest a motivational basis of the effect. In fact, a combination of both influencing factors

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would be very plausible, but the contribution of both interindividual and situational variables is overdue.

In total, the dissertation at hand supplies answers to several important questions concerning the effects of self-relevance (independent of stimulus familiarity) and the presented findings encourage a variety of further research in the field of self-relevance effects. Strikingly, what can be concluded from the empirical results described within this dissertation, is the conception of the *self as a specific, complex network of associations between different concepts* and the assumption that *self-relevance facilitates stimulus integration rather than guiding attention automatically*.

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## **Declaration of Authorship**

I hereby certify that this thesis has been composed by me and is based on my own work, unless stated otherwise. No other person's work has been used without due acknowledgement in this thesis. All references have been quoted and all sources of information have been specifically mentioned.

## **Eigenständigkeitserklärung (deutsch)**

Hiermit erkläre ich, dass die vorliegende Arbeit von mir und basierend auf meiner Arbeit entstanden ist. Keine andere Person war an der Erstellung beteiligt, die nicht in der Danksagung zu dieser Arbeit erwähnt wird. Alle Referenzen werden entsprechend zitiert und Daten aus anderen Quellen werden unter Angabe der Quelle als solche gekennzeichnet.

Trier, \_\_\_\_\_

Date/Datum

\_\_\_\_\_

Signature/Unterschrift