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A FRAME-BASED ANALYSIS OF SYNAESTHETIC METAPHORS

ABSTRACT: The aim of this paper is to use a frame-based account to explain some empirical findings regarding the accessibility of synaesthetic metaphors. Therefore, some results of empirical studies will be discussed with regard to the question of how much it matters whether the concept of the source domain in a synaesthetic metaphor is a scalar or a quality concept. Furthermore, typed frames are introduced, and it is explained how the notion of a *minimal upper attribute* can be used in the analysis of adjective-noun compounds. Finally, frames are used to analyze synaesthetic metaphors; it turns out that they offer an adequate basis for the explanation of different accessibility rates found in empirical studies.

1. INTRODUCTION

For our concept of synaesthetic metaphors, we follow prominent theories of metaphor which state that a metaphor is a mapping of a concept from some source domain onto a concept of some target domain, where the target and source domains are not identical (Black 1962; Lakoff and

Johnson 1980). For illustration, in the metaphorical sentence (1) a concept from the source domain of bodily motion (expressed by the verb 'bow') is mapped onto a concept from a geographical target domain (expressed by the noun 'road').

(1) The road bows down into the valley.

The characteristic of synaesthetic metaphors is that their concepts are taken from domains involving sensory perception. For example, in the metaphor *silent color* the source domain concept *silent* is mapped onto the target domain concept *color*. The two concepts belong to different perceptual domains; the first centered around the sense modality *sound* and the second around the sense modality *vision*.

In this paper, we are specifically concerned with synaesthetic metaphors and thus will not be discussing synaesthesia in a neurological sense. We restrict ourselves to synaesthetic metaphors where the target and source domain concepts are taken from the perceptual domains of *vision*, *taste*, *touch*, *smell* and *sound*.[1] Furthermore, we only discuss metaphors expressed by adjective-noun compounds.

The remainder of this paper is structured as follows: Sect. 2 discusses some results of empirical studies with regard to the adequacy of directionality theses and with regard to how much it matters whether the source domain concept in a synaesthetic metaphor is a scalar or a quality concept. Sect. 3 introduces typed frames and explains how the notion of a *minimal upper attribute* can be used in the analysis of non-metaphorical adjective-noun compounds and synaesthetic metaphors.

2. SYNAESTHETIC METAPHORS

2.1. Directionality theses based on analyses of lyric corpora

One of the first systematic studies of synaesthetic metaphors has to do with the directionality of mapping. Ullmann (1967) claims that concepts of so-called lower senses (on the left of the hierarchy shown in Fig. 1) should be more likely to occur in the source domain of synaesthetic metaphors, while concepts of higher senses (on the right side of the hierarchy) should be more likely to occur in the target domain. His thesis of directionality entails that a metaphor with a concept from a

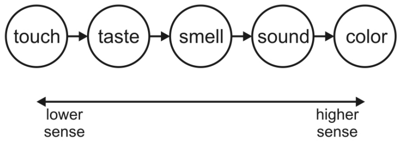


Figure 1: Directionality and the hierarchy of the senses according to Ullmann (1967).

source domain lower in the hierarchy of sense modalities than the concept of the target domain should tend to occur more frequently in use than a metaphor with the reverse direction of domains. For example, a metaphor like *cold redness* (a mapping of *touch* onto *color*) is in line with the postulated hierarchy and therefore should be preferred to *red coldness* (a mapping of *color* onto *touch*), which contradicts the hierarchy. To establish his claim Ullmann analyzes examples from lyric poetry like the following one:

> Soft music like a perfume, and a sweet light
> Golden with audible odours exquisite
> Swathe me with cerements for eternity.
> (Arthur Symons, "The Opium-Smoker", cit. after Ullmann 1967:275)

Subsequent directionality claims concerning the mapping of synaesthetic metaphors are more differentiated and complex (Williams 1976; Shen 1997; Yu 2003). Williams (1976), for example, proposes a non-linear hierarchy of sense modalities. Common to all the mentioned studies is that they are based on the analysis of lyric poetry. Hence the proposed directionality theses were constructed by counting the frequency of occurrences of different synaesthetic metaphors in lyric poetry.

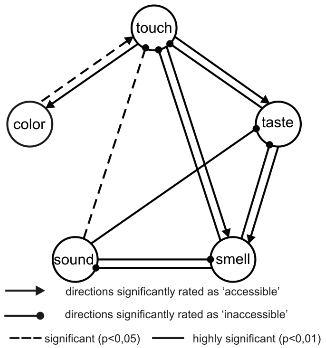
It seems reasonable to postulate that if any version of the directionality thesis is empirically adequate for a certain language, then the choice of source and target domains should significantly influence the cognitive accessibility of a synaesthetic metaphor. Hence one can expect to find such constraints in non-poetic uses of language as well.

2.2. A directionality thesis based on emprical studies

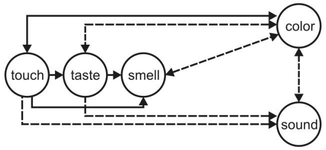
In Werning *et al.* (2006) we empirically tested the directionality claims that have been made in the literature. German-speaking participants were asked to judge whether a certain synaesthetic metaphor was intuitively accessible or not. For that purpose, we constructed 57 random synaesthetic metaphors in the form of adjective-noun compounds. The adjectives represented the source domain concepts, while the nouns represented the target domain concepts.[2] Care was taken to ensure that for each metaphor with a certain succession of source and target domain (e.g., *cold smell*) the complementary metaphor (*smelling coldness*) was tested as well. The idea behind concentrating on adjective-noun compounds was that they would constitute the simplest possible metaphors and so not induce reference to a relevant context of some sort. It was very important to rule out the possibility that contextual factors would influence the accessibility of the metaphors under consideration. The adjective-noun compounds presented to the test subjects were not preselected with respect to their interpretability and thus expressed only potentially understandable synaesthetic metaphors. In the following we use the term 'synaesthetic metaphor' for any expression which is built according to our definition, whether or not it is interpretable.

Our results suggest that three independent factors seem to influence the cognitive accessibility of synaesthetic metaphors: the frequency of the metaphor's head (all word frequencies were taken from the German version of the CELEX corpus Baayen *et al.* 1995, which consists of about six million items), the morphological derivation of the adjectival modifier and the directionality of the mapping. The more frequent the metaphor's head is in the language, the more accessible the metaphor. Additionally, the accessibility of the metaphor decreases if the modifier is morphologically derived from a verb or a noun. These two factors might affect all interpretations of metaphorical or even non-metaphorical expressions, but the influence of directionality seems to occur specifically in the case of synaesthetic metaphors. Fig. 2 shows the results of our analysis with respect to directionality. (The factors of word frequency and morphological complexity were carefully ruled out in the study in order to focus squarely on directionality.)

Our results do suggest support for the thesis that the accessibility of a synaesthetic metaphor does depend on the direction of the map-



(a) Significant influences of directionality on accessibility. Shown are all directionalities which indicate a significant influence on accessibility.



(b) Directionality hierarchy. Solid arrows show directions significantly rated as 'accessible', while dotted arrows represent neither significantly impeded nor enhanced directions. A missing arrow indicates a direction significantly rated as 'inaccessible'.

Figure 2: Identified influences of directionality and the resulting directionality hierarchy according to empirical data by Werning *et al.* (2006).

ping from source to target domain concepts, and on which source and target domains (vision, hearing, taste, etc.) are involved in the metaphor. In Fig. 2(a) the deviations from the null hypothesis, that there is no directionality effect, are shown. Based on these accessibility results the directionality hierarchy in Fig. 2(b) was constructed. The hierarchy in Fig. 2(b) is a graphical illustration of our directionality claim, while Fig. 2(a) presents the results of the empirical investigation, on which the directionality thesis is based.[3] We are aware that this directionality claim does not hold for every metaphor. Insofar as it expresses only statistical tendencies, deviations are to be expected. However, there were some cases of striking differences in accessibility that might be problematic for our directionality thesis. These cases could not be explained in terms of frequency, derivation or directionality. For example: there are differences in subjects' judgments regarding the following two metaphors, which both map a visual concept onto an auditory concept:

(2) gelbe Ruhe ('yellow silence')

(3) blasser Klang ('pale sound')

All subjects assessed the first metaphor (2) as 'not accessible', but for 93% the second metaphor (3) was accessible, despite the fact that the modifiers are both not morphologically derived, and that the metaphors share the same directionality (*color* onto *sound*). Moreover, the frequency of the adjective 'gelb' (203) exceeds the frequency of the adjective 'blass' (101).

One has to ask, how can the mentioned findings be explained, and especially, how do these two metaphors differ? There is a basic difference between the concept types *yellow* and *pale*. *Pale* is a scalar concept, while *yellow* is a quality concept. Scalar concepts not only form antonym pairs (e.g. pale and colorful, hot and cold), they also need a contextually fixed norm for their interpretation. Quality concepts like color terms, by contrast, do not form antonym pairs, but instead form an incompatible set. This means that, for example, *red* can not be seen as the opposite of *blue* and *blue* can not be seen as the opposite of *green*.

The following sentences mentioned by Lehrer and Lehrer (1982:495) illustrate this difference between scalar and quality concepts:

(4) If the coffee is cool and the tea is lukewarm, which one is warmer?

(5) If Jane's dress is orange and Mary's dress is yellow, whose dress is more purple?

According to Lehrer and Lehrer (1982), answering the first question should be easy; surely the tea is warmer than the coffee. But what about the second sentence? Which dress is more purple? It is possible to say: 'orange is more purple-like then yellow', but this does not indicate that *orange* and *yellow* lie on a purple-scale.

As a consequence of the differences between the two concept types, the comparative forms of scalar adjectives and quality adjectives are interpreted in different ways.

(6) This color is brighter than that color.

A sentence like (6) means that the first color occupies a higher place on the brightness scale than the second color. The use of a comparative form of a color concept, by contrast, has a rather different interpretation.

(7) This color is more red than that color.

Sentence (7) means that there is a focal red and that one of the colors is more similar to this focal red then the other color. Lehrer and Lehrer (1982:495) state: "[...] the scalability of color terms, as exhibited by phrases such as *very red*, *fairly red*, *A is more red than B* indicates not a single dimensional color scale, but rather the existence of a focal point for each color". Thus, comparative forms are interpreted differently depending on the type of concept they are applied to. Thus, the distinction between these concept types is linguistically motivated.

In order to test the influence of these concept types on the accessibility of synaesthetic metaphors, we did a second study (Beseoglu and Fleischhauer 2007) and created a new random set of synaesthetic metaphors. This time, the source domain was restricted to quality and scalar concepts from the domain of *vision*. All these concepts were combined with three different heads: *Geräusch* 'sound', *Geruch* 'smell' and *Geschmack* 'taste'.[4] By restricting ourselves to these three nouns we ruled out another factor potentially influencing our data: concepts like *taste* and *sweet* differ fundamentally in that the first one denotes an *attribute* and the second a *value* of that attribute (cf. Sect. 3.1). Note that we did not use *touch* as a target domain concept because the German analogue *Gefühl* is ambigously used. The metaphors were judged with respect to their intuitive accessibility by 85 German-speaking participants. In addition to accessibility, the same variables as in the the first study were analyzed. Neither the frequency of the target and source domain concepts nor the morphological derivation of the adjectives used in the source domain showed any effect on metaphor accessibility. Thus, it remains unclear whether these factors have any influence on the accessibility of synaesthetic metaphors. Concept type was the only variable which had an effect in our study.

The null hypothesis was again that there would be no directionality effects on the accessibility of synaesthetic metaphors, thus an equipartition was expected. We used the value +1 for 'accessible' and -1 for

	quality concept onto smell	quality concept onto taste	quality concept onto sound
N	209	212	216
mean value	-0.59**	-0.47**	-0.69**

	scalar concept onto smell	scalar concept onto taste	scalar concept onto sound
N	214	211	208
mean value	-0.07	0.15	0.43

Table 1: Comparison of metaphors with quality and scalar concept types as source domain concept.

'not accessible', so that a mean value of 0 would indicate the null hypothesis. A t-test was used to calculate significant deviations ($p < 0.05$) from the expected mean value. The results are shown in Table 1. Highly significant results are marked with '**' ($p < 0.01$).

The data in Table 1 show a clear difference between the accessibility of metaphors involving quality concepts and those using scalar concepts. All directions with *quality concepts* in the source domain were significantly impeded. On the other hand, when *scalar concepts* were used in the source domain they exhibited no significant inhibition of accessibility. We even observed a significant enhancement in the case of mapping a scalar concept onto *sound*.

Given this data, it seems reasonable to divide the concepts associated with sense modalities into two different classes (*scalar* and *quality*), both for linguistic reasons and in view of the empirical results. The differentiation shown by our study indicates a further variable influencing the accessibility of synaesthetic metaphors, namely concept type.[5]

To sum up, in the second study metaphors like *bright sound* or *gloomy smell* appeared to be 'accessible', while metaphors like *red sound* or *black smell* appeared to be 'inaccessible'. Now the question arises: how can this dependency of accessibility on the concept types involved in metaphors be explained?

3. A FRAME-BASED ANALYSIS OF SYNAESTHETIC METAPHORS

The empirical findings from the preceding section show that metaphors like *bright sound* or *gloomy smell* were judged 'accessible' by our test subjects, while metaphors like *red sound* or *black smell* were judged 'inaccessible'. In this section, we will present a theoretical approach which could explain why a metaphor's accessibility depends on the concept type of its modifier (i.e., the adjective). For that purpose, we will first give a short introduction to our notion of frames, which is based on Petersen (2007). We will then explain how we analyze non-metaphorical adjective-noun compounds using frames. Finally, we will give a sketch of how our analysis of non-metaphorical adjective-noun compounds can be applied to the analysis of synaesthetic metaphors and how that could explain the observed differences regarding the accessibility judgements.

3.1. Introduction to frames

According to Barsalou (1992:21), frames, understood as recursive attribute-value structures, "provide the fundamental representation of knowledge in human cognition". We assume that a concept frame consists of a set of attribute-value pairs, where each attribute specifies a property by which the described concept is characterized. Since attributes specify properties of very different kinds, one could establish an attribute classification with classes like *role attributes* (e.g., DRIVER of a car, TEACHER of a class, MOTHER of a person), *attributive attributes* (e.g., COLOR, LENGTH, TASTE of an object), *part-of attributes* (e.g., ENGINE of a car, HEAD of a person), and so forth (cf. Guarino 1992).[6] However, such a classification is of no interest for the present study. The only claim concerning attributes which we will assume here is that attributes in frames assign unique values to concepts and are thus functional relations. As an example, Fig. 3 shows a frame for a car drawn in its graph representation,[7] where arcs are labeled by attributes and nodes by types (the latter are introduced in the remainder of this section).

Values assigned to attributes are frames themselves and determine the concrete realization of the property given by the attribute. That is, assigning the value red to the attribute COLOR in a *car* frame means that a car represented by the frame is red. Such values may be either complex or atomic. Atomic values are not structured internally. Examples of atomic values in Fig. 3 are 4-cylinder as a value for CYLINDER or diesel as a value for FUEL. By contrast, complex values are themselves represented by frames, meaning that the value is further specified by attributes of its own. For example, our *car* frame contains an attribute ENGINE, whose value is further specified by attributes like DISPLACEMENT, CYLINDER or FUEL. Moreover, attribute values may be rather unspecific, as can be seen with the attributes COLOR, MILEAGE, DISPLACEMENT in the example frame. The recursive structure of frames enables them to represent concepts at many different levels of detail.

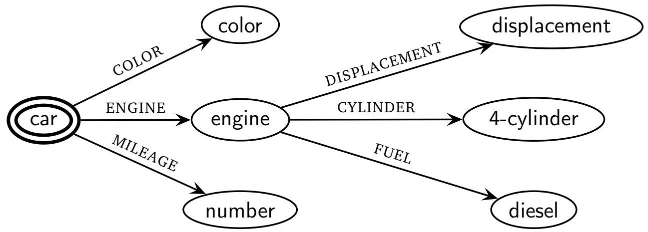


Figure 3: An exemplary *car* frame in graph representation.

Unfortunately, the frame representation as described above imposes no formal restrictions on the values which can be assigned to an attribute. This can lead to such undesirable frames as [SHAPE: red] or [INTENSITY: round], where neither red nor round are generally considered as appropriate values for their respective attributes. We therefore need some means to restrict the set of admissible frames. One solution to this problem, which is common in Computational Linguistics (cf. Carpenter 1992), is to assign *types* to frames and to order these types in a *type signature* with respect to their specificity (e.g., apple is a subtype of fruit, which is itself a subtype of object). An exemplary type signature is shown in Fig. 4. The type signature is enriched with appropriateness conditions (ACs), e.g., <COLOR:color> is an AC for the type object. ACs fulfill two tasks: First, they restrict the set of adequate attributes for frames of a certain type (e.g., frames of type object may carry the attributes COLOR and SHAPE, but not TASTE). Second, ACs specify the range of appropriate values for each attribute by requiring all values of an attribute to be of at least a certain type. Hence if the type fruit carries

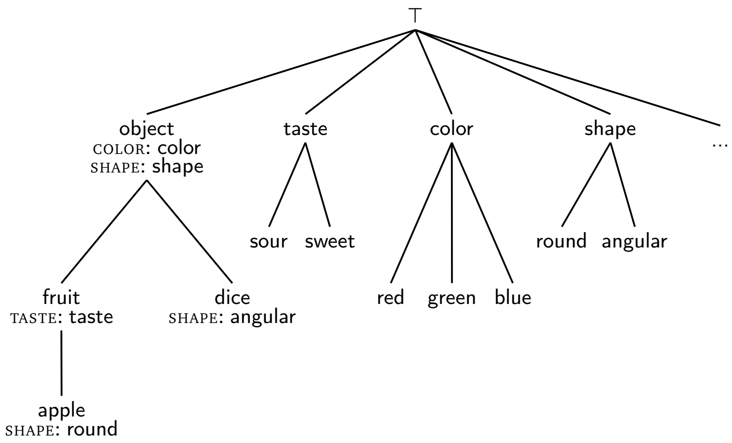


Figure 4: Example type signature

the AC <TASTE: taste>, this means that the attribute TASTE in a frame of type fruit may take only values of type taste or of a subtype of taste (e.g., sour, sweet, ...). Note that it is possible to assign to attributes underspecified values like taste instead of concrete values like sweet.

In order to capture the ontological status of attributes we follow the arguments given in Guarino (1992) and postulate that in a type signature, any attribute must also occur as a type, i.e., the attribute set is a subset of the type set (for details see Petersen 2007). As a consequence, an expression such as "taste" can have two different meanings: if it is written as "taste", it refers to the type taste, and if it is written as "TASTE", it refers to the attribute TASTE. For every attribute ATTR the type signature contains an introductory type which carries the AC <ATTR: attr>. Subtypes inherit all ACs from their supertypes, but may also tighten them up, so that more specific values are prescribed for the attribute given. E.g., supposing that all apples are round and are represented by frames of type apple, we could tighten up the AC <SHAPE: shape> at type object to <SHAPE: round> at type apple. Since our type signatures are monotonic inheritance hierarchies, loosening of ACs is (at least in the standard approach) not allowed. It is important to note

that we require our frames to be well-typed, by which we mean that all attributes occurring in a frame have to be declared appropriate in the ACs.

It is common to use natural language expressions as type labels in order to improve readability and to intuitively indicate the intended semantics of the types. However, one should keep in mind that a type signature usually orders types of very different semantic categories: that is, they correspond to all kinds of *attributes* (see discussion above), to *attributions* like *red* or *long*, to sortal concepts like *apple*, and so forth. Hence the subtype relation cannot be interpreted in a uniform way.[8] For example, the relation between *color* and *red* is different from the relation between *fruit* and *apple*: the former relates an attributive attribute to a possible value or attribution, the latter relates a category to a subcategory.

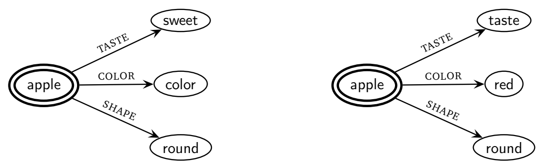
3.2. Frames for adjective-noun compounds

Before we can approach synaesthetic metaphors in terms of frames, we need to introduce our frame-based analysis of adjective-noun compounds, since all metaphors from Sect. 2 are in that form.[9] Therefore, we consider the following two example phrases:

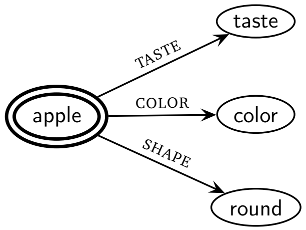
(8) red apple

(9) sweet apple

Obviously, the composition of *red* and *apple* yields a frame with the value of COLOR being red, while the composition of *sweet* and *apple* yields a frame with the value of TASTE being sweet:



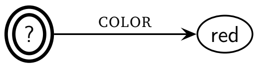
Both frames differ from the general apple frame



only with respect to the value of a single attribute.[10] Hence the semantic contribution of the adjective to the compound is twofold: (1) it selects an attribute and (2) it modifies the attribute value.

The corresponding type signature in Fig. 4 reveals an interesting relationship between the selected attribute and the inserted value. The adjective corresponds to a type which is a subtype of the attribute type. This is not an accidental, but rather a systematic relationship following from our definition of type signatures. First of all, we claim that each attribute ATTR is introduced into the type signature by an AC of the form <ATTR: attr> at some type Intro(ATTR), which means that only frames of a subtype of attr are appropriate values for ATTR. Secondly, we say that ACs are monotonically inherited by subtypes (cf. Sect. 3.1) and that subtypes may not loosen inherited ACs, but only tighten them up. This guarantees that any appropriate value val of an attribute ATTR has to be a subtype of attr. In such a case we say that the attribute ATTR is an *upper attribute* (UA) of the type val. If ATTR is minimal in the sense that it is the most specific upper attribute of val, then ATTR is said to be the *minimal upper attribute* (MUA) of val (cf. Petersen 2007). E.g., the MUA of red in Fig. 4 would be COLOR since color is the minimal supertype of red which is also used as an attribute in some AC (i.e., <COLOR: color> at type object).

Coming back to the problem of adjective-noun compounds, we assume that in general the attribute selected by the adjective is the MUA of the type it corresponds to. For our discussion here it does not matter whether one supposes that adjectives constitute their own semantic frames or not. Reasonable frames for the adjectives *red* and *sweet* would be



and

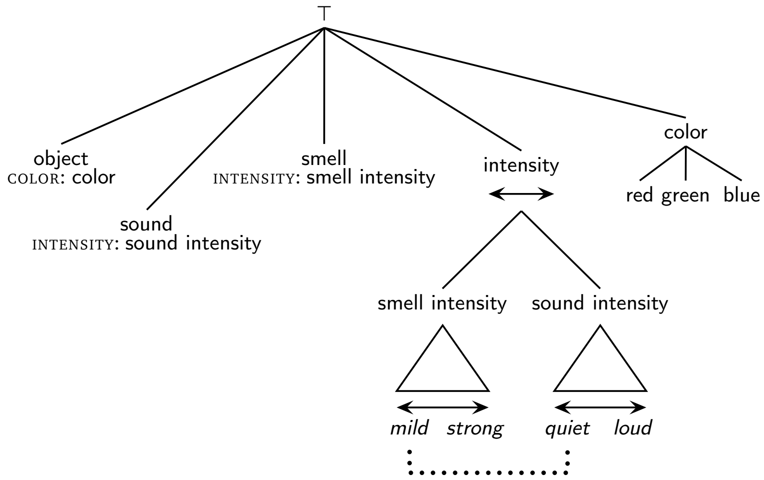



Figure 5: Type signature for examples (10) and (11)

with an open possessor argument. The possessor argument has only one attribute, namely being the dimension along which the adjective predicates. This dimension is the MUA of the attribute's value.[11]

3.3. *Using frames to model synaesthetic metaphors*

In what follows, we will concentrate on a frame-based analysis of synaesthetic metaphors. We claim that, in principle, our language processing system can process simple metaphorical expressions in pretty much the same way as non-metaphorical ones, as long as they come in the form of adjective-noun compounds. Our analysis from the preceding section should therefore also account for the metaphors from Sect. 2. As discussed there, the accessibility of synaesthetic metaphors heavily depends on whether the modifying adjective is a quality concept or a scalar concept. We use the following examples to illustrate our analysis of synaesthetic metaphors using frames:

(10) quiet smell

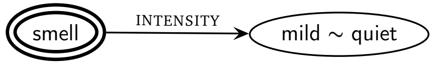
(11) red smell

Along with these examples we assume a type signature containing (among other types) a type intensity which introduces an intensity scale into the type signature (see Fig. 5). The type intensity is a supertype of both smell intensity and sound intensity. The former one is a scale of smell intensities, containing the antonyms mild and strong as its extremes. The latter one is a scale of sound intensities, containing quiet and loud as its extremes. Since we only use intensity, but not smell intensity or sound intensity, as an attribute, the MUA of all four types is INTENSITY. The types smell intensity and sound intensity fulfill two tasks: first, each establishes its own particular specification of the intensity scale and second, they are referred to in the ACs at the types sound and smell in order to adequately restrict the values of the attribute INTENSITY with respect to the frame node to which INTENSITY is attached. Hence in frames of type smell the value of INTENSITY is restricted to subtypes of smell intensity, while in frames of type sound it is restricted to subtypes of sound intensity.

Although it seems like an arbitrary choice to assume that neither smell intensity nor sound intensity are used as attributes, we think that there are good reasons to do so. Imagine a dog pile with a very intense smell: a frame for such a concept certainly has an attribute SMELL whose value is a frame of type smell. Inside such a *smell* frame, an attribute INTENSITY makes more sense than an attribute SMELL INTENSITY since the context is already restricted to attributes pertaining to *smell*. As another example, consider a frame for the concept of a personal computer. Of course one would say that a computer has a volume (i.e., a sound intensity), but it is not the volume of the computer itself, but rather the intensity of the sound of its fans, so there would be an attribute FAN, which itself has a value with an attribute SOUND, which again has a value with an attribute INTENSITY. One can still introduce some kind of shortcut attribute named VOLUME in the *personal computer* frame whose value refers to the value of the attribute INTENSITY in the *sound* frame.

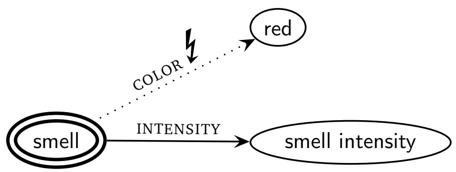
According to our analysis of adjective-noun compounds, (10) would result in a frame like

But according to the type signature in Fig. 5, the possible values for INTENSITY in a *smell* frame must be subtypes of smell intensity. The type quiet, however, is no subtype of smell intensity and the frame is thus invalid. In order to explain why this metaphor is grasped anyway, we assume that the invalid frame is *re*interpreted by drawing an analogy from quiet to mild:



Since both quiet and mild belong to the lower section of their respective scales, since these scales are both specifications of the scale which is introduced at type intensity, and since quiet and mild are linked by sharing the same MUA INTENSITY, it seems reasonable to draw an analogy between quiet and mild. So basically, the metaphorical expression *quiet smell* is analyzed like the non-metaphorical expression *red apple*. The only difference is that the resulting frame of the first expression needs an extra reinterpretation step in order to make it valid with respect to the ACs.

In contrast to (10), example (11) *red smell* fails to be interpretable. This follows from the fact that the MUA of red is COLOR, which is not an adequate attribute for a frame of type smell:



A reinterpretation of an attribute value is only possible if the attribute is licensed by the ACs. In the example phrase *red smell*, the attribute COLOR is not licensed by the ACs of type smell, so the frame must be invalid, regardless of the value assigned to COLOR. The ability to reinterpret *quiet smell* results from the fact that the MUA of quiet already is an attribute of the *smell* frame and that an analogy can be drawn between quiet and mild (indicated by the dotted line in Fig. 5).

4. CONCLUSION

In the previous section we presented our analysis of synaesthetic metaphors using frames. We applied a technique originally developed for the analysis of non-metaphorical adjective-noun compounds to the analysis of metaphorical adjective-noun compounds and discovered that there are (at least) two kinds of frames resulting from this approach: (1) frames bearing inadequate attributes and (2) frames having inappropriate values for certain (adequate) attributes. Metaphors corresponding to frames of type (1) seem to be uninterpretable, while metaphors of type (2) can be comprehended as long as it is possible to reinterpret the inappropriate value as an appropriate value. This reinterpretation depends on whether the two values share a common MUA and lie on the same phase of a scale. Hence our frame approach models the empirical findings presented in Sect. 2 by stating that synaesthetic metaphors with scalar concepts as modifiers are more likely to be accessible than synaesthetic metaphors with quality concepts in the modifier position. These findings cannot be explained in terms of directionality of metaphorical mapping.

We are aware that our frame-based analysis of synaesthetic metaphors presented in the preceding section depends on several modeling decisions. For example, the MUA of a type may change, whenever the order of the types in the type hierarchy is changed. However, seeing *red* as a special kind of *color* and thus modeling red as a subtype of color seems very plausible to us. Also the decision to stipulate that *sound intensity* and *smell intensity* are special kinds of *intensity* is reasonable. Furthermore, the analysis depends on the hypothesis that an inappropriate value may be reinterpreted by an appropriate value if both are connected by a shared MUA and if they bear an analogy to each other, while an inadequate attribute has to be rejected and can thus never enter a frame. This hypothesis seems reasonable, too, since grasping an inadequate attribute cognitively involves more than drawing a simple analogy.

As discussed in the preceding section, the frame-based approach to the analysis of adjective-noun compounds provides an explanatory approach to the fact that a synaesthetic metaphor with a scalar adjective like *quiet smell* is predominantly judged accessible (Werning *et al.* 2006:2370) in spite of violating the directionality hierarchy. Remember

that the metaphor *quiet smell* is a mapping of *sound* onto *smell*, which is significantly impeded according to the mentioned directionality studies. Hence the scalar vs. qualitative distinction is more crucial for the accessibility of synaesthetic metaphors than the directionality hierarchy. The empirical results concerning this distinction are reflected by the frame-based analysis and the described step of reinterpretation since quality and scalar concepts differ with regard to the MUA of their respective types.

However, we are aware of the fact that some empirical findings, even in our own data, contradict our hypotheses. For example, the metaphor *dark smell* was judged nearly inaccessible (Beseoglu and Fleischhauer 2007:714), while an expression like *red sweet* shows higher accessibility results than our account predicts. We expect that *red sweet* is not analyzed by simply reinterpreting attribute values of a *sweet* frame. Instead, while processing *red sweet*, a more complex *fruit* frame is constructed which states that red fruits are more likely to taste sweet than green ones. A formal frame-based account for approaching such more general metaphors still needs to be developed. Also, more empirical research has to be done in order to test our hypotheses.

Petersen and Werning (2007) discusses the cognitive adequacy of the frame model for the decomposition of concepts. It has been shown that by applying the paradigm of object-related neural synchronization, a biologically motivated model for the cortical implementation of frames can be developed. The present study confirms once more our confidence in the frame approach by showing that the presented empirical data can be directly explained in our model. Hence we follow Barsalou in his statement, cited above, that frames provide the fundamental representation of knowledge in human cognition.

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Notes

[1]We do not consider emotions to be perceptual concepts and thus exclude them from our analysis.

[2]The source and target domain concepts that were used are listed in Appendix A.

[3]For details see Werning *et al.* (2006).

[4]The source and target domain concepts that were used are listed in Appendix B.

[5]In a yet unpublished study, Beseoglu, Kiguradze, and Fleischhauer acquired the same results regarding Georgian speakers and Georgian metaphors. It is also the case in Georgian that scalar concepts appear to be better modifiers than quality concepts.

[6]In this paper, attributes are written in small capitals and types are written in a sans-serif font.

[7]Apart from the graph representation, we also use a matrix representation, which is more suited for embedding frames in text. In this form, a frame is embraced in square brackets and contains a list of attribute-value pairs in the form 'ATTRIBUTE: value', where each value may again be a frame embraced in square brackets.

[8]For a comprehensive discussion of these problems consult the literature on formal ontologies (cf. Guarino 1992; Guarino and Welty 2000).

[9]The analysis given here is taken from a simple frame-based language processing system which aims at the translation of natural-language expressions to frames on a best-effort basis.

[10]To simplify matters, we use greatly reduced frames which only contain a small fraction of the concept's content, especially leaving out all syntactic information. In a frame-based language processing system, the frames shown here would occur as subframes of larger frames representing language signs as a whole and containing, besides the semantic content, also syntactic information. Modeling such frames would go beyond the scope of this paper.

[11]Note that in most frame-based language processing systems, frames with empty argument nodes cannot be expressed.

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A. Used adjectives and nouns from Werning *et al.* (2006)

adjective	noun	modality
blass	Blässe	color
blau	Blau	color
duftend	Duft	smell
dunkel	Dunkelheit	color
farbig	Farbe	color
glatt	Glätte	touch
glänzend	Glanz	color
grün	Grün	color
hart	Härte	touch
heiß	Hitze	touch
hell	Helligkeit	color
kalt	Kälte	touch
klingend	Klang	sound
kühl	Kühle	touch
lärmend	Lärm	sound
melodisch	Melodie	sound
mild	Milde	taste
nass	Nässe	touch
riechend	Geruch	smell
rot	Rot	color
ruhig	Ruhe	sound
scharf	Schärfe	taste
scheppernd	Scheppern	sound
schmeckend	Geschmack	taste
still	Stille	sound
stinkend	Gestank	smell
süß	Süße	taste
weiß	Weiß	color

B. Used adjectives and nouns from Beseoglu and Fleischhauer (2007)

B.1. List of adjectives used

dimension concepts	quality concepts
blass	grau
dunkel	rot
finster	blau
glänzend	weiß
hell	schwarz
matt	braun

B.2. List of nouns used

noun	sense modality
Geräusch	sound
Geruch	smell
Geschmack	taste