Chapter 1

Aiming with → arrows ← at particles: Towards a conceptual analysis of directional meaning components in German particle verbs

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This article presents a case study on the contributions of prepositional particles to the meanings of German particle verbs (such as *anstrahlen* 'to beam/smile at' and *aufgeben* 'to give up'). Based on a set of 16 "concept images", two-dimensional directional arrow pictographs, 60 experiment participants selected one or more concept images for a systematically composed set of 270 German particle verbs and their 30 base verbs. We formulate a series of hypotheses for the meanings of nine constituent particle types (*ab, an, auf, aus, ein, mit, nach, vor, zu*) and investigate them in the light of the concept image selections. Qualitative and quantitative analyses indicate that our hypotheses are largely confirmed, across three source domains varying in their abstractness (Machines & Tools, Force, Sound), as well as across well-known vs. unknown particle verbs. The particles exhibit individual concept image profiles, and they vary in their flexibility to provide predominant directions; for example, while *auf* is rather consistently perceived as contributing an upward/right direction to a particle verb meaning, *an* shows similarly strong preferences for a set of concept images; in both cases, these tendencies are observed across source domains.

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1 Introduction

German particle verbs (PVs) are complex, separable verb structures such as *anstrahlen/strahlen …an* 'to beam/smile at' that combine a prefix particle (*an*) with a base verb (*strahlen* 'to beam/smile'). PVs represent a type of multiword expressions, which are generally known as a "pain in the neck for NLP" (Sag et al. 2002). Even more, German PVs pose a specific challenge, because the particles are highly ambiguous; e.g., the particle *an* has a partitive meaning in *anbeißen* 'to take a bite', a cumulative meaning in *anhäufen* 'to pile up', and a topological meaning in *anbinden* 'to tie to' (Springorum 2011). In addition, the particles often trigger meaning shifts of the base verbs (BVs), cf. Springorum, Utt, et al. (2013); Frassinelli et al. (2017); Köper & Schulte im Walde (2018); Schulte im Walde et al. (2018); e.g., the PV *abschminken* with the BV *schminken* 'to put on make-up' has a literal meaning in a concrete context 'to remove make-up', as in example (1), and a metaphorical meaning in an abstract context 'to forget about something', as in example (2).

(1) Den Lippenstift kannst du dir abschminken.
the lipstick can you yourself [ab] put on make-up
'You can remove the lipstick.'

(2) Den Job kannst du dir abschminken.
the job can you yourself [ab] put on make-up
'You can forget about the job.'

Not only the particle types but also the particle verbs as a whole often have more than a single reading. For example, the PV *anstrahlen* not only means 'to beam at' but also 'to smile at', when derived from the metaphorical meaning of *strahlen* 'to beam', i.e. 'to smile'. The PV *abnehmen* not only means 'to take off/away', but can also be used to express 'to reduce' as an incremental interpretation of 'to take off/away'; in addition, it has obtained the specific sense 'to reduce weight'. The semantic decomposition in the latter two examples seems to be less transparent than in the previous ones, thus indicating different degrees of PV compositionality. Accordingly, we also find opaque compositions such as *aufhören* 'to stop', where the semantics of the BV *hören* 'to hear' does not seem to provide any contribution to the PV meaning at all. Such examples are the reason why PV composition is often deemed idosyncratic, cf. Kratzer (2003).

In this chapter, we explore the meaning contribution of particle types to the meanings of German particle verbs across three semantic domains of base verbs, which vary in their degree of abstractness: Machines & Tools, Force, and Sound.

Within our study, we focus on prepositional particle types and the role of directionality. In this vein, Section 2 will motivate our assumptions about particle meanings in German PVs in more detail, before Section 3 presents the design, hypotheses and results of an experiment that collected human judgements on directionality in particle meanings. Section 4 discusses the experiment data and reflects on our preceding assumptions about prepositional particle meanings.

2 Particle meanings

2.1 Basic particle meanings and contexts

For the course of this article, we assume that each particle type has a restricted number of simple primary meanings, which we refer to as *basic meanings.* This is in accordance with Lindner (1983), who identifies a prototypical sense for the English verb particle *out* involving 'paths in the spatial domain'. Without a BV context, the basic particle meanings are underspecified first, and then resolved by contextual constraints provided by the BV. For example, the separation introduced by the particle *ab* in the context of the BV *nehmen* 'to take' evokes a change of state 'to take off/away', whereas in the context of the BV *schminken* 'to put on make up' it evokes a duration 'to remove make up' generated by a sequence of separations. However, not only the BV but also further context has to be taken into account, as there are ambiguous PVs with varying particle meaning contributions. For example, regarding the metaphorical meaning of *abschminken* in example (2), *ab* introduces only a single separation event, in contrast to the sequence of separation events in the literal PV reading.

Previous research has pointed out regularities in the interpretation of particle meanings associated with semantically coherent classes of base verbs, cf. Stiebels (1996); Lechler & Roßdeutscher (2009); Kliche (2011); Springorum (2011). For example, DIRECTION and CONTACT represent two independent readings of *an*, among others: The PV in example (3) belongs to the DIRECTION meaning class, suggesting that *an* assigns a direction to the BV, whereas in example (4) the PV carries a CONTACT particle meaning. In combination with a movement BV as in example (5), the particle again introduces a direction. In addition, the meaning of *anfahren* requires a decreasing distance, which results in a contact when maximal. Therefore, *anfahren* represents an example with meaning components from both classes, DIRECTION and CONTACT. Examples (3–5) show that particle senses vary in their complexity, and they also illustrate the limits of a hard class assignment.

(3) Karin schaut das Bild an.
Karin look the picture [an]
'Karin looks at the picture.'

(4) Karin klebt die Briefmarke an.
Karin stick the stamp [an]
'Karin sticks on the stamp.'

(5) Karin fährt die Laterne an.
Karin drive the street lamp [an]
'Karin drives against the street lamp.'

In addition, a classification of PVs should not only take lexical information into account. Sentimental connotations, associations to other sensory input, (nature) forces, and dimensionality are just as well involved in the process of sense development. For example, the metaphorical PV *abklappern* (lit. [ab]+'to clatter') illustrates that sensory information can be understood as a part of the PV meaning: *abklappern* creates an ideophone, which is mapped to the verb event, and leads to the meaning-shifted sense 'to pursue something successively', as illustrated by example (6). This perception-based meaning shift process is discussed in more detail by Springorum, Utt, et al. (2013).

(6) Sie klapperte die Geschäfte nach tollen Büchern ab.
she clattered the shops for great books [ab]
'She successively searched through the shops for great books.'

Particle meaning is not only influenced by its context, but also provides an influence on the meaning of the context. For example, participants in a sentence generation experiment relying on systematically created PV neologisms (neoPVs) were asked to generate sentences for neoPV types such as *antöten* ([an]+'to kill') and *abschlafen* ([ab]+'to sleep'), without being provided any context (Springorum, Schulte im Walde, et al. 2013). The participants did not only show considerable agreement regarding potential neoPV meanings, but also often agreed in their strategy of dealing with particle senses, in cases where the BV meaning did not fit the PV senses, as in the case of *antöten*, where 'to kill' introduces an absolute change of state, and the generated sentences mainly suggested an *an* meaning of PARTIAL AFFECTEDNESS, thus introducing quantification over event parts. This meaning typically cannot be applied to a verb with an absolute change of state, such as *töten*, but the participants obviously re-conceptualised the change-of-state BV *töten* as a process verb, which gradually approximates the final state of death. Often, adverbial specifications such as *fast tot* 'nearly dead' were added, which supported the above assumptions. The meaning components in the PV based on the BV were thus adjusted dependent on the particle meaning.

In sum, we define the meaning of a PV as either a direct composition of possible meaning components of particle and BV (if they are compatible), or alternatively as meaning-shifted particle and BV meaning components in strong interaction with the context. On the one hand, PVs can be assigned to discrete particle classes, based on semantically coherent groups of BVs, but on the other hand the classes need to be flexible to allow semantic changes if necessary. At first these two alternative options might seem contradictory, but from a diachronic perspective they reflect two natural processes of sense development. For example, according to Waldron (1979) "new words should first be used in rather specialised senses and subsequently be generalised" and "when such words have once achieved general status we use them without reflection upon their former restricted or technical sense". In addition, "the reverse process, in which a general word is given a special meaning in a restricted context, is just as common". In this sense, the polysemy of particles is considered as a result of adjustment processes of basic meanings to recurring contextual conditions.

2.2 Spatial grounds of particle meanings

As we are focussing on PVs with prepositional particles, we assume that particles are spatially grounded, similar to preposition meanings. Prepositions indicate spatial fundamentals, as discussed by Herskovits (1986) and Dirven (1993), among others. They structure the physical space and determine "language-specific concepts built up in mental space" (Dirven 1993). Simlarly, Gärdenfors (2004) claims that prepositions are "primarily spatial relations" and create "spatially structured mental representations", when used with non-locational words. In order to structure space, it has to be perceived through our senses, with vision representing the predominant human sense (Viberg 1983).

Furthermore, Jackendoff (1983) understands "perception as an interaction between environmental input and active principles in the mind, that impose structure on that input". He demonstrates his view by ambiguous pictures from the school of Gestalt psychology. Lakoff (1987) refers to the "spatialisation of form hypothesis" by using the term *image schema*, which he defines as "schematic descriptions of meaning concepts". So perception of space cannot be separated from cognitive conceptualisation, and (meaning) concepts are often analogies of structures, to define space through perception. Although there are "significant differences between mental imagery and image schemas", according to Gibbs Jr.

& Colston (1995) there is "good evidence that both spatial and visual representations exist for mental imagery".

We assume that prepositional particles – simlarly to prepositions – introduce relations to structure space and to add verb-related meaning components, such as aspectual or temporal modifications. These relations can be captured by image schemas as "dynamic analogue representations of spatial relations as movement in space" (Gibbs Jr. & Colston 1995) to describe aspects of PV meaning. Accordingly, earlier investigations connect (spatial) concepts with phrasal verbs. Going beyond the already mentioned work by Lindner (1983), Morgan (1997) provides an extension for metaphorical readings of some *out* phrasal verbs. From a didactic point of view, Side (1990) and Abreu & Vieira (2008) discuss the advantages of using image schemas in order to learn phrasal verbs. In a psycholinguistic setting, Richardson et al. (2001) carried out experiments to show that basic images can be related to spatial and abstract verbal meanings.

A semiotic perspective of schematic descriptions is provided by Frutiger (1987), who defines the essential task of a schema as description with the help of literally pictured elements, to divide objects into different parts, instead of only using words.

3 Experiment

This section presents the material, design, hypotheses and results of the experiment that collected human judgements on spatial aspects in particle meanings.

3.1 Material

3.1.1 Verb data

The German particle verbs for the experiment were generated systematically, based on a pre-selected set of base verbs and a pre-selected set of particles. We relied on base verbs from three different semantic domains, Machines and Tools (MnT), Force and Sound, which differ regarding their degree of concreteness. Furthermore, Kövecses (2002) categorises MnT and Force domains as common source domains for metaphors. The verbs belonging to the MnT domain (such as *hämmern* 'to hammer' and *schaufeln* 'to dig') are easy to imagine and represent very concrete BVs. In comparison, the verbs from the Force domain (such as *drücken* 'to press' and *quetschen* 'to squeeze') are less concrete, as the force itself is not perceivable directly, but only through interactions of its concrete entities encoded in the verb arguments. The verbs from the Sound domain (such as *schreien* 'to cry' and *jaulen* 'to yowl') represent intransitive verbs and define the most abstract source domain.

For each of the three domains we chose a total of ten base verbs that we thought as not obviously ambiguous among the three classes, cf. the Appendix (page 32). These 30 BVs were then systematically composed to PVs using nine different prepositional particles. We only took into account particles that cannot also be used in German prefix verbs: *ab, an, auf, aus, ein, mit, nach, vor, zu*. In this way, we obtained 300 verbs (30 selected BVs and 270 generated PVs) as target verbs for the experiment. Due to the systematic composition of the PVs, also PV neologisms (neoPVs) were part of this data set. As part of the experiment tasks, the experiment participants were thus asked to rate a PV as a neologism, such that our analyses can distinguish between existing PVs vs. PV neologisms. Approximately half of the PVs were rated as neoPVs (153 out of 270 PVs), see Section 3.2.

3.1.2 Concept images

Although there are many semantic analyses based on concepts and frequently illustrated by visual schemas or pictographs, as to our knowledge there is no general systematic standard available. We therefore decided to define visual representations for directional concepts from scratch. As source for inspiration, we relied on Dreyfuss' symbol sourcebook, a very detailed collection of various kinds of symbols from many different areas (Dreyfuss 1972), and on a more descriptive sign derivation in Frutiger (1987). We defined the set of directional pictographs as shown in Figure 1. The pictographs were intended to be as simple as possible, in order not to distract from the actual information, but at the same time they should allow possibly alternative interpretations. We refer to our simplified pictographs as *concept images*.

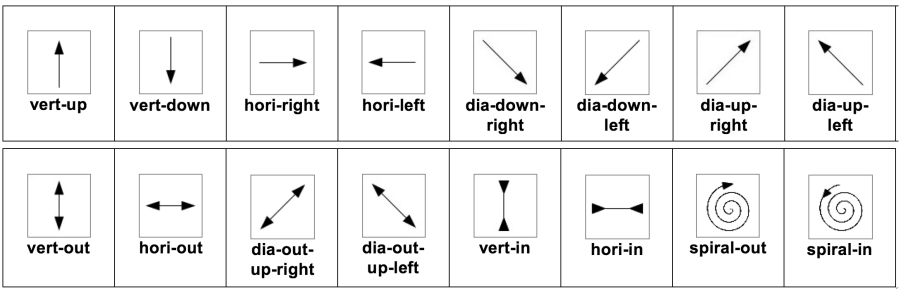

Figure 1: Set of concept images.

Although the number of directions in space is infinite, a simplified conceptual reduction into a two-dimensional setting is in many cases sufficient, because "the salient dimensions of the world reinforce the horizontal and the vertical" (Tversky 2011). We therefore included vertical arrows for upward and downward directions (VERT-UP, VERT-DOWN), horizontal right and left directions (HORI-RIGHT, HORI-LEFT), and also the four diagonal directions (DIA-DOWN-RIGHT, DIA-DOWN-LEFT, DIA-UP-RIGHT, DIA-UP-LEFT). To represent single object-oriented center-periphery directions as expansion or constriction, we use lines with arrow heads at both ends.

The outward-pointing arrow heads (VERT-OUT, HORI-OUT, DIA-OUT-UP-RIGHT, DIA-OUT-UP-LEFT) correspond to expansion, and the inward-pointing arrow heads (VERT-IN, HORI-IN) correspond to constriction. To distinguish between asymmetrical and uniform center-periphery directions, two arrows with concentric curved lines were added (SPIRAL-OUT, SPIRAL-IN). The total set of concept images contains 16 pictograms.

3.2 Design

The experiment was performed as follows: The 300 verbs were distributed randomly over 6 lists with 50 verbs each. The random distribution was balanced for BVs vs. PVs, BV source domain, particle type and (non-)neologism[1], such that each file contained equal proportions of these.

Each verb was judged by ≈20 participants, non-experts (mostly students on campus), without payment. They were presented a randomly ordered list of the target verbs (printed out or as a file), together with the concept images. For each verb, the participants were first asked to choose between one of the following statements, to check on whether they knew the PVs:

1. unknown and difficult to understand;
2. unknown but easy to understand;
3. infrequent usage but known;
4. frequent usage and known.

[1]At this point, we did not yet have human ratings for PV neologisms, so we used a pre-categorisation which considered a PV as neoPV if it did not appear in the *SdeWaC* web corpus containing 880 million words (Faaß & Eckart 2013).

These ratings provided a participant-dependent categorisation of PVs (and also of BVs, but those were not relevant for us) into existing PVs vs. PV neologisms on a four-point scale.

Then the participants were asked to mark those concept images which fit the meaning of the target verb. Multiple marks were allowed while we did not explicitly allow the participants to not select a concept image because we wanted to enforce a selection. However, we asked the participants to describe an alternative image if they decided that none of our concept images fit. In that way they would only fall back to not providing any selection if they really could not settle on a concept image.

3.3 Hypotheses

The main goal of our study was to investigate whether prepositional particles within German particle verbs can be associated with directional concepts, which are visually represented as concept images. As the basis for interpreting the experiment results, this section provides example-based and experience-driven hypotheses for the above-mentioned nine particle types regarding their most prevalent readings. Regarding the particles *ab, an* and *auf*, we in addition rely on detailed formal semantic analyses (Lechler & Roßdeutscher 2009; Kliche 2011; Springorum 2011).

Further than discussing the primary concepts as originating from the spatial domain, we also include time into the interpretation of space, as "knowledge of space frequently comes from motion in time, from exploring environments and piecing together the parts" (Tversky 2011). Furthermore, relying on Boroditsky (2001), who analyses time with the help of spatial metaphors, "concepts of space appear to be primary", concepts of time can be derived from concepts of space.

3.3.1 *ab*

ab has a basic meaning derived from the gravity force that causes objects to fall. This motion describes a DOWN directional meaning which may be represented by the concept image VERT-DOWN. An example is the particle verb *ablaufen* 'to run down' in example (7) where the downward meaning can only be contributed by the particle and not by the BV *laufen* 'to run'. In contrast, example (8) with *absinken* 'to sink' the event of the BV *sinken* 'to sink' already introduces a downward direction. The difference between the BV and the PV meanings is that the BV events refer to an atelic continuous downward motion, as arising from the gravity force DOWN direction, while the PV event is resultative, so a direction is spanned between the pre-state and the resulting state of the object affected by the gravity force. That is, in example (8) the pre- and result states are the locations of the ship before and after the sinking motion. The PV meaning is thereby almost synonymous to the BV meaning, which only describes the downward motion of the ship, and in addition introduces a result state.

(7) Das Wasser läuft ab.
the water runs [ab]
'The water runs off.'

(8) Das Schiff sinkt ab.
the ship sink [ab]
'The ship sinks.'

The PV *abfallen* in example (9) also describes a downward direction with pre- and result states, regarding the button affected by gravity. Here, however, we find a further meaning component: the detachment of the button, a mereological part of the jacket, has to be caused by some force. This example (9) suggests that the particle *ab* may also contribute a SEPARATION meaning, which is – according to previous lexical semantic analyses – a productive reading for this particle (Kliche 2011). Often, it is not gravity but other intentional forces which are causing detachments, as in example (10) with the PV *abreißen* 'to pull off'. Here, the direction related to the force may even overwrite the basic downward direction of *ab*, which means that the particle only contributes the SEPARATION meaning component to the PV. The directions are explicitly specified through the semantics of the BV, through further contextual clues, or remain unspecified as in example (10). In addition to the gravity-dependent default direction described by VERT-DOWN, a "neutral", gravity-independent horizontal direction described by HORI-RIGHT or HORI-LEFT might therefore represent an alternative choice of concept image.

(9) Der Knopf fällt von der Jacke ab.
the button fall off the jacket [ab]
'The button falls off the jacket.'

(10) Karin reißt den Knopf von der Jacke ab.
Karin pull the button off the jacket [ab]
'Karin pulls the button off the jacket.'

The continuous variant of the discrete SEPARATION reading is the DECREASE OF PROXIMITY reading which occurs with motion verbs as in example (11). Here the alignment with the conceptual direction of time becomes obvious. Similarly, in sentences as in example (12) with *absitzen* 'to wait/endure', lit. 'to sit off' in an abstract context, the spatially grounded basic concept has to be transferred to available abstract dimensions, which are different from space. Regarding *absitzen*, the abstract context *seminar* belongs to the time domain, so that the direction of the particle *ab* can conceptually only align with the conceptual orientation of the time dimension. The conceptual direction is thereby spanned between the starting point and an iteration of separations of mereological parts, which are time intervals. This leads to a PROGRESS reading which may be combined with a conceptually vertical value scale (Tversky 2011) to a VALUE DECREASE meaning, as in example (13). Combining the PROGRESS and the VALUE DECREASE dimensions, DIA-DOWN-RIGHT is another concept to be expected for the particle *ab*. This idea is comparable to Talmy (2000)'s force dynamics, a conceptual notion of forces split up into different components and relations, which can be applied to various domains.

(11) Karin fährt (von Stuttgart) ab.
Karin drive (from Stuttgart) [ab]
'Karin departs (from Stuttgart).'

(12) Karin sitzt das Seminar ab.
Karin sits the seminar [ab]
'Karin endures the seminar.'

(13) Karin wertet (mit ihrer Kritik) alles ab.
Karin values (with her criticism) everything [ab]
'Karin devaluates everything (with her criticism).'

3.3.2 *an*

an introduces a direction which is force-independent in its primary meaning, as in example (14), repeated from example (3), with the PV *anschauen* 'to look at' derived from the perception BV *schauen* 'to look' in a spatial context. The direction of human sight – with a neutral head position which is horizontal by default – determines this conceptual direction. Given this, *an* can be represented by the concept images HORI-RIGHT and HORI-LEFT.

(14) Karin schaut das Bild an.
Karin look the picture [an]
'Karin looks at the picture.'

In contexts with forces, e.g. as derived from motion, the particle *an* contributes an INCREASE OF PROXIMITY reading in analogy to the DECREASE OF PROXIMITY reading of *ab*. Its direction is aligned with the direction of the goal of the motion expressed by its object to which the proximity is increased, cf. example (15) in comparison to example (11). Due to this goal we expect the concept image HORI-RIGHT with the right-pointing arrow, since the future in Western cultures is on a horizontal timeline conceptually located on the right.

(15) Karin fährt Stuttgart an.
Karin drive Stuttgart [an]
'Karin drives towards Stuttgart.'

If the argument represents a concrete object, as *the street lamp* in example (16), repeated from example (5), the relation introduced by *an* can be understood as MAXIMAL PROXIMITY, such that there is a CONTACT situation in the result state of the verb. In addition, we find readings as in example (17) with *anhämmern* 'to attach by hammering', where the particle *an* introduces a direction orthogonal to the vertical surface of a wall, again enforcing a CONTACT reading. In comparison, examples (18) and (19) refering to horizontal surfaces – where the direction of *an* needs to be vertical – are only semi-acceptable. This strengthens the assumption that the basic conceptual direction of *an* is horizontal, and that HORI-RIGHT and HORI-LEFT will be selected as predominant representations for this reading.

(16) Karin fährt die Laterne an.
Karin drive the street lamp [an]
'Karin drives against the street lamp.'

(17) Karin hämmert das Bild an die Wand an.
Karin hammer the picture at the wall [an]
'Karin hammers the picture to the wall.'

(18) ? Karin hämmert das Bild an die Tischplatte an.
Karin hammer the picture at the table top [an]
'Karin hammers the picture to the table top.'

(19) ? Karin hämmert das Bild an die Decke an.
Karin hammer the picture at the ceiling [an]
'Karin hammers the picture to the ceiling.'

In example (20) with the PV *anfressen* 'to nibble' the particle *an* introduces a relation that identifies parts of the verbal object which are affected by the verb event. Here, the mouse nibbles only on some parts of the apple, scraping through the surface. Conceptually this is an extension of the MAXIMAL PROXIMITY reading, where the maximum is exceeded and results in a damaged surface of the direct object affected by the verb event. The meaning contributed by *an* is therefore a PARTIAL AFFECTEDNESS relation.

(20) Die Maus frisst den Apfel an.
the mouse nibble the apple [an]
'The mouse nibbles at the apple.'

In intransitive contexts with an abstract verb notion as in example (21) with the PV *anlaufen* 'to start' where the BV *laufen* 'to run' comes with its abstract and unspecific progress sense and therefore conceptually only provides the dimension of time, the particle *an* spans an abstract conceptual direction between the beginning of the time interval and an unspecified point later within this interval. In such cases, the conceptual direction of the particle is resolved to a meaning which refers to EVENT INITIATION.

(21) Der Motor läuft an.
the motor go [an]
'The motor starts.'

In contexts as in example (22) where the BV *heizen* 'to heat' provides a value dimension, the conceptual direction of *an* is not only associated with the time dimension of the verb event but also with the vertical-value heat dimension. This means that the particle not only introduces the heating event initiation, but also a temperature rise along the timeline. This suggests that DIA-UP-RIGHT, the synthesis of HORI-RIGHT and VERT-UP is a suitable concept.

(22) Karin heizt den Ofen an.
Karin heat the oven [an]
'Karin heats the oven.'

3.3.3 *auf*

auf's basic meaning represents the upward direction UP, the opposite direction of the basic meaning of *ab* as derived from the directional alignment with the falling motion caused by gravity. That is, *auf*'s basic meaning is the direction derived from motions caused by forces which overcome gravity. This is the case in example (23), where the upward direction is a result of the gravity-countering shooting force.

(23) Das Wasser schießt auf.
The water shoot [auf]
'The water shoots up.'

Overcoming gravity often includes an elevation of an object, where a prominent position is more likely in the field of visual perception of an experiencer. Given this, the particle *auf* is also used to mark a COMING-INTO-PERCEPTION sense as in example (24), where startled birds suddenly become visually perceivable when they lift up from the ground.

(24) Karin schreckt die Vögel auf.
Karin scare the birds [auf]
'Karin startles the birds.'

The spatially derived basic UP meaning can also refer to a sudden increase of noise, volume or pitch, when resolved in a Sound source-domain context, as in example (25). This mapping of spatial height to a scale is very productive, and often the particle contributes an INCREASE meaning as in example (26). Therefore we expect the concept image VERT-UP to be associated with this particle.

(25) Karin schreit auf.
Karin cry [auf]
'Karin crys out.'

(26) Karin dreht die Musik auf.
Karin turn the music [auf]
'Karin turns up the music.'

If *auf* appears in contexts where it can only be applied to the time dimension, the spatially derived UP is conceptually spanned between beginning and end of the time interval of the BV event. In this interpretation of the directional concepts the particle covers the whole event time interval (in contrast to *an*'s EVENT INITIATION interpretation, which only covers the first parts of the event time interval but says nothing about the endpoint), so that its semantic contribution is a COMPLETENESS reading as in example (27). The event duration is determined by the direct object, as in the consumption of a cookie in example (28). The scale adds a vertical value dimension to the horizontal time notion, measuring the progress and making DIA-UP-RIGHT a plausible concept image.

(27) Karin arbeitet die Aufgaben der letzen Woche auf.
Karin worked the tasks the last week [auf]
'Karin finishes off the tasks of the last week.'

(28) Karin isst den Keks auf.
Karin eats the cookie [auf]
'Karin eats up the cookie.'

3.3.4 *aus*

aus typically refers to an expansion in the spatial domain, as illustrated by example (29). The growth of an object may also be conceptualised as direction originating from a point within the object, so overall the concepts VERT-OUT, HORI-OUT as well as DIA-OUT-UP-RIGHT, DIA-OUT-UP-LEFT and SPIRAL-OUT are legitimised.

(29) Das Universum dehnt sich aus.
The universe expand itself [aus]
'The universe expands.'

From an object-extrinsic perspective the particle introduces a specified closed area – conceptually understood as a container – to distinguish between an inside and an outside. With the help of an imaginary container concept, it is possible to relate our two-dimensional concept images to this particle meaning.[2] The concept image HORI-RIGHT represents a plausible concept in order to describe the gravity-independent "default" direction pointing from an inside to an outside area. E.g., in (30) the concept image HORI-RIGHT may indicate the pulling direction from the bed moved out of its box, the imaginary container.

(30) Karin zieht das Schlafsofa aus.
Karin pull the sofa bed [aus]
'Karin opens the sofa bed.'

3.3.5 *ein*

ein can introduce a shrinking or constriction of an object, as in example (31), and therefore be related to the inward-orientated concepts VERT-IN, HORI-IN as well as SPIRAL-IN. In analogy to the change from inside to outside described by *aus*, *ein* can also refer to a change from an outside to an inside area, as in example (32). This may be depicted with VERT-DOWN, again refering to an imaginary conceptual container representing the transition direction from the outside area to an inside, e.g. through the default opening of a container at the top.

[2] A more appropriate notion of containers requires a spatial concept with a higher dimensional complexity and is thus going beyond the scope of the current study.

(31) Der Igel rollt sich ein.
the hedgehog roll itself [ein]
'The hedgehog rolls itself up.'

(32) Karin wirft eine Münze in den Automaten ein.
Karin throw a coin in the vending machine [ein]
'Karin throws a coin into the vending machine.'

3.3.6 *mit*

mit introduces a relation between two arguments of which one may be implicit, as in example (33). The particle does not provide additional information regarding these arguments, hence both symmetrical HORI-IN and HORI-OUT concepts, which allow no inferences regarding an imbalance, are assumed possible representations for *mit*.

(33) Karin geht (mit ihrer Schwester) in das Schwimmbad mit.
Karin go with her sister in the pool [mit]
'Karin joins her sister to go to the pool.'

3.3.7 *nach/vor*

nach and *vor* introduce orderings in space which are gravity-independent and can therefore describe horizontal relations, suggesting HORI-LEFT and HORI-RIGHT as their concepts. The main difference between *nach* and *vor* is their conceptual perspective on the one-dimensional ordering. *nach* focuses on something which can be conceptualised as following, as behind or as an end, cf. example (34), whereas *vor* focuses on a conceptual front or a beginning, as in example (35).

(34) Karin schmeißt ihrem Freund eine Zeitung nach.
Karin throw her boyfriend a newspaper [nach]
'Karin throws a newspaper after her boyfriend.'

(35) Karin drängelt sich vor.
Karin push herself [vor]
'Karin jumps the queue.'

3.3.8 *zu*

zu provides a gravity-independent direction in the spatial domain similar to *an*, and in addition introduces an assignment or an intention. The assignment can be concrete, as in example (36), or abstract, as in example (37), whereas the intention meaning is always abstract, so that the particle's direction also tends to be abstract, as in example (38). We predict that the particle always originates from the spatial domain, and that DIA-UP-RIGHT therefore represents a plausible concept for this P, because it is a synthesis of HORI-RIGHT, the default direction, and VERT-UP, the goal representation. The fulfilment of an intention requires effort, i.e., a force, and therefore presupposes resistance. In analogy to *auf*'s countergravity direction, the direction introduced by *zu* is also a counter-direction facing resistance to reach the intended goal. Without further specification and with gravity as the default force to be overcome, the intention to reach a goal can conceptually be described with VERT-UP.

(36) Karin fährt auf die Stadt zu.
Karin drive up the city [zu]
'Karin drives towards the city.'

(37) Karin ordnet die Telefonnummer Emelie zu.
Karin arrange the phone number Emelie [zu]
'Karin assigns the phone number to Emelie.'

(38) Karin schneidet den Stoff genau nach Plan zu.
Karin cut the fabric exactly after plan [zu]
'Karin cuts the fabric exactly according to the plan.'

3.4 Concept image selections

In this section, we present an overview of the actual selections of concept images by our experiment participants, before Section 4 discusses them in light of the hypotheses just introduced. The dataset is publicly available at http://www.ims.uni-stuttgart.de/data/pv-ci.

3.4.1 Dataset

As mentioned in Section 3.2, the 300 verbs were distributed randomly over 6 lists with 50 verbs each, and each list was judged by ≈20 non-experts. Given that participants might have refrained from judging a verb they did not know, the resulting distribution of the number of participant judgements over verb types differs slightly. Most of the verbs received between 16 and 20 judgements.

In total, we obtained judgements across 5,509 verb instances (including only those instances where at least one concept image had been chosen). Table 1 shows the number of concept images that were selected across verb instances. 3,192 (58%) of the target verb instances were assigned exactly one concept image; 1,556 (28%) received two concept images; 11% received three or four, and 2% were assigned between five and 16 concept images. Abstracting over target verbs to particle types, each of the nine particle types received between 540 and 560 judgements across concept images, i.e., we have a rather homogenous number of concept images across particle types.

Table 1: Number of selected concept images per verb instance.

No. of concept images	1	2	3	4	5	6	7	8	9	10–16
No. of verbs	3,192	1,556	456	178	72	31	11	7	1	5

Figure 2 shows the average ratings to which degree the target verbs were (un)known to the experiment participants (cf. Section 3.2). Setting a threshold in the middle of the scale 1–4 at 2.5 classifies 153 of the 300 target verbs as neologisms. All 30 base verbs were known to the participants and received an average rating >3.2. Figure 3 shows that the distribution of unknown vs. known PVs varies across the domains of their underlying BVs. PVs with Force and Sound BVs are more prominent among unknown PVs, while PVs with Machines and Tools BVs are more prominent among known PVs.

3.4.2 Concept image selection across particles

The heat map in Figure 4 shows the preferences for selected concept images across particle types, calculated as follows. For each annotated verb instance we determined the proportion of selection for each concept image. For example, if two concept images were chosen by a specific participant and for a specific verb instance, each of the two concept images received a proportion of 0.5, and all others received proportions of 0. These proportions were then averaged over all PV instances with the same particle type, across participants. The color red indicates strong preferences of a specific concept image selected for a specific particle type, the color blue indicates weak preferences. Overall, the average preferences range from 0.004 to 0.214.

The heat map demonstrates that the particles exhibit clearly different concept image profiles. The particle *auf*, for example, achieved the overall strongest preference of 0.214 for the concept image DIA-UP-RIGHT, and a preference of 0.136 for VERT-UP. *ab* shows preferences of ≥0.150 for the concepts DIA-DOWN-RIGHT and VERT-DOWN. *an*, *nach* and *vor* are associated most strongly with HORI-

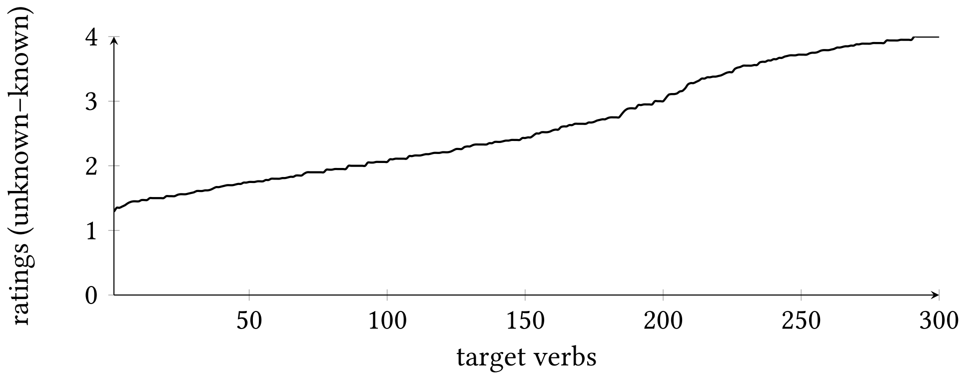

Figure 2: Ratings of unknown/known target verbs.

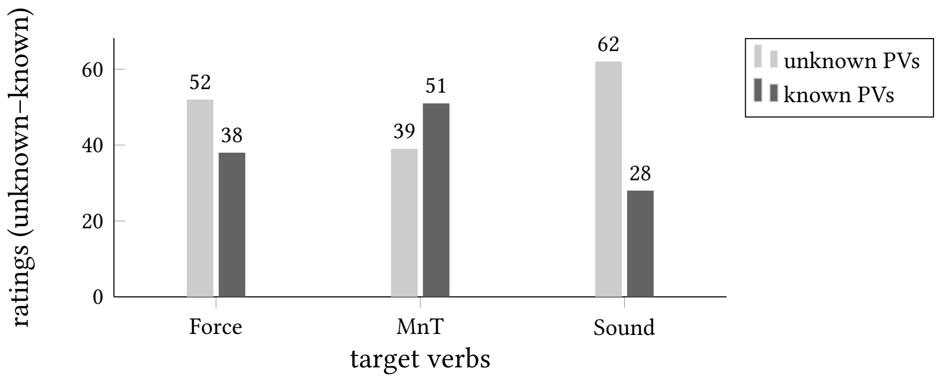

Figure 3: Unknown/known target particle verbs across domains.

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.016	0.046	0.136	0.047	0.023	0.029	0.018	0.051	0.017
vert-down	0.15	0.065	0.072	0.086	0.142	0.056	0.066	0.067	0.102
hori-right	0.048	0.138	0.032	0.051	0.057	0.102	0.167	0.158	0.076
hori-left	0.03	0.032	0.012	0.016	0.033	0.023	0.045	0.085	0.041
dia-down-right	0.165	0.088	0.033	0.088	0.106	0.039	0.079	0.074	0.089
dia-down-left	0.077	0.034	0.009	0.029	0.052	0.018	0.036	0.032	0.04
dia-up-right	0.055	0.107	0.214	0.107	0.052	0.071	0.067	0.108	0.052
dia-up-left	0.017	0.012	0.026	0.019	0.008	0.017	0.009	0.027	0.011
vert-out	0.049	0.05	0.069	0.07	0.046	0.069	0.051	0.045	0.051
hori-out	0.092	0.069	0.085	0.119	0.048	0.158	0.079	0.059	0.05
dia-out-up-right	0.027	0.027	0.046	0.049	0.018	0.053	0.032	0.039	0.012
dia-out-up-left	0.037	0.022	0.013	0.019	0.01	0.029	0.027	0.02	0.024
vert-in	0.03	0.047	0.052	0.027	0.064	0.047	0.045	0.031	0.085
hori-in	0.053	0.101	0.049	0.051	0.118	0.124	0.075	0.073	0.171
spiral-out	0.088	0.093	0.106	0.157	0.062	0.104	0.111	0.089	0.058
spiral-in	0.066	0.068	0.044	0.066	0.162	0.061	0.095	0.043	0.12

Figure 4: Concept image selection across particle types.

RIGHT (preferences 0.138–0.167), *aus* with SPIRAL-OUT (preference 0.157), *ein* with SPIRAL-IN and VERT-DOWN (preferences 0.162 and 0.142, respectively), *mit* with HORI-OUT (preference 0.158), and *zu* with HORI-IN (preference 0.171).

3.4.3 Concept image selection across existing PVs and PV neologisms

The heat maps in Figure 5 specify the particle selections of concept images from Figure 4 regarding the participants' ratings of PV knowledge. That is, the upper plot in Figure 5 shows concept image preferences across particles for well-known PVs with an average rating ≥2.5, and the lower plot shows concept image preferences across particles for rather unknown PVs with an average rating <2.5.

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.018	0.068	0.116	0.058	0.045	0.021	0.013	0.076	0.025
vert-down	0.149	0.064	0.067	0.114	0.14	0.044	0.045	0.074	0.115
hori-right	0.057	0.131	0.03	0.022	0.065	0.161	0.16	0.163	0.058
hori-left	0.037	0.027	0.015	0.008	0.023	0.013	0.028	0.108	0.036
dia-down-right	0.15	0.092	0.042	0.08	0.125	0.038	0.078	0.07	0.069
dia-down-left	0.063	0.024	0.009	0.034	0.05	0.007	0.033	0.025	0.046
dia-up-right	0.028	0.135	0.257	0.11	0.045	0.091	0.08	0.108	0.061
dia-up-left	0.018	0.014	0.032	0.012	0.006	0.033	0.006	0.044	0.008
vert-out	0.026	0.041	0.049	0.083	0.032	0.072	0.035	0.029	0.039
hori-out	0.134	0.071	0.065	0.072	0.044	0.169	0.062	0.075	0.051
dia-out-up-right	0.027	0.017	0.037	0.039	0.021	0.056	0.016	0.03	0.017
dia-out-up-left	0.036	0.017	0.014	0.016	0.01	0.031	0.022	0.025	0.027
vert-in	0.028	0.019	0.046	0.034	0.071	0.03	0.039	0.033	0.079
hori-in	0.063	0.069	0.059	0.078	0.127	0.077	0.06	0.042	0.159
spiral-out	0.095	0.121	0.111	0.162	0.071	0.099	0.184	0.064	0.068
spiral-in	0.071	0.09	0.05	0.076	0.124	0.058	0.138	0.033	0.142

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.014	0.02	0.159	0.04	0.01	0.033	0.021	0.034	0.008
vert-down	0.15	0.066	0.077	0.066	0.143	0.062	0.08	0.061	0.086
hori-right	0.042	0.148	0.033	0.07	0.052	0.072	0.171	0.154	0.098
hori-left	0.025	0.04	0.01	0.021	0.039	0.029	0.055	0.07	0.047
dia-down-right	0.176	0.082	0.023	0.093	0.093	0.039	0.079	0.077	0.112
dia-down-left	0.087	0.047	0.008	0.025	0.053	0.023	0.037	0.036	0.034
dia-up-right	0.073	0.073	0.164	0.105	0.056	0.061	0.058	0.107	0.041
dia-up-left	0.016	0.01	0.02	0.024	0.009	0.01	0.011	0.016	0.015
vert-out	0.066	0.061	0.092	0.06	0.055	0.067	0.061	0.057	0.065
hori-out	0.063	0.066	0.108	0.152	0.05	0.152	0.091	0.047	0.05
dia-out-up-right	0.027	0.039	0.057	0.055	0.015	0.052	0.042	0.045	0.007
dia-out-up-left	0.037	0.028	0.013	0.021	0.011	0.028	0.03	0.017	0.021
vert-in	0.031	0.081	0.058	0.023	0.059	0.055	0.048	0.03	0.091
hori-in	0.046	0.141	0.038	0.031	0.112	0.147	0.085	0.094	0.184
spiral-out	0.084	0.058	0.101	0.154	0.056	0.106	0.064	0.107	0.046
spiral-in	0.062	0.04	0.039	0.059	0.186	0.063	0.067	0.049	0.096

Figure 5: Concept image selection across particles and (un)known PVs.

While we expected to see more strongly associated concept images for particles in rather unknown PVs (refering to some predominant meaning contribution(s)), this is the case for the majority of particle types (e.g., DIA-DOWN-RIGHT for *ab*; HORI-RIGHT and HORI-IN for *an*; SPIRAL-IN for *ein*; HORI-RIGHT for *nach* and *vor*; HORI-IN for *zu*) but not for *auf, aus* and *mit*. The figure however indicates that the concept image selections are largely stable for well-known vs. unknown particle verbs, i.e., the strongest preferences of particle types regarding concept images show up in both heat maps.

3.4.4 Concept image selection across BV source domains

Figures 6 and 7 look into concept image selection across BV source domains. Figure 6 presents the average preferences of selected concept images per domain across all particle types. It shows that already the base verbs exhibit clearly different concept image profiles when taking into account the respective source domain. For Force BVs, the inward-pointing concept images HORI-IN (0.221) and VERT-IN (0.125) received the strongest preferences; for MnT BVs, the concept image VERT-DOWN (0.154) received the predominant amount of selections, followed by a set of concept images with preferences of ≈0.100–0.110: SPIRAL-OUT, VERT-OUT, DIA-DOWN-RIGHT and HORI-OUT, favouring downward- and outward-pointing arrow types while being rather flexible, i.e., with less strong overall preferences; for Sound BVs, the strongly favoured concept image is SPIRAL-OUT (0.288), with a set of secondary selections for HORI-OUT (0.134), SPIRAL-IN (0.109) and VERT-OUT (0.097), favouring spiral-shaped and outward-directed arrows.

	Force	MnT	Sound
vert-up	0.023	0.052	0.053
vert-down	0.096	0.154	0.035
hori-right	0.061	0.035	0.02
hori-left	0.013	0.016	0.008
dia-down-right	0.059	0.1	0.024
dia-down-left	0.016	0.021	0.007
dia-up-right	0.029	0.064	0.063
dia-up-left	0.005	0.008	0
vert-out	0.054	0.111	0.097
hori-out	0.096	0.098	0.134
dia-out-up-right	0.028	0.056	0.05
dia-out-up-left	0.016	0.031	0.03
vert-in	0.125	0.013	0.045
hori-in	0.221	0.033	0.036
spiral-out	0.087	0.117	0.288
spiral-in	0.071	0.09	0.109

Figure 6: Concept image selection across base verbs, with reference to their domains.

Figure 7 demonstrates that the BV patterns across concept images are partly preserved and partly over-written when combining the BVs with specific particles. PVs composed of Force BVs and particles *an, ein, mit, zu* inherit the strong

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.003	0.021	0.064	0.045	0.004	0.044	0.015	0.042	0.015
vert-down	0.148	0.068	0.098	0.066	0.129	0.075	0.065	0.096	0.091
hori-right	0.049	0.138	0.05	0.077	0.072	0.107	0.151	0.174	0.047
hori-left	0.056	0.047	0.019	0.019	0.047	0.034	0.058	0.09	0.047
dia-down-right	0.153	0.068	0.027	0.036	0.089	0.024	0.061	0.043	0.064
dia-down-left	0.071	0.035	0.013	0.011	0.041	0.02	0.039	0.032	0.014
dia-up-right	0.069	0.068	0.163	0.085	0.023	0.05	0.055	0.082	0.032
dia-up-left	0.02	0.016	0.029	0.028	0.004	0.004	0.019	0.034	0.017
vert-out	0.044	0.04	0.048	0.067	0.037	0.047	0.043	0.02	0.023
hori-out	0.092	0.048	0.1	0.173	0.041	0.108	0.059	0.054	0.023
dia-out-up-right	0.019	0.026	0.043	0.051	0.013	0.043	0.019	0.03	0.011
dia-out-up-left	0.028	0.03	0.013	0.021	0.003	0.029	0.023	0.015	0.033
vert-in	0.067	0.081	0.114	0.063	0.131	0.086	0.09	0.048	0.157
hori-in	0.104	0.211	0.124	0.098	0.213	0.23	0.158	0.167	0.286
spiral-out	0.035	0.047	0.048	0.103	0.051	0.051	0.066	0.036	0.049
spiral-in	0.042	0.055	0.049	0.057	0.103	0.047	0.08	0.037	0.09

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.028	0.07	0.144	0.071	0.06	0.024	0.016	0.055	0.026
vert-down	0.172	0.077	0.07	0.127	0.161	0.076	0.094	0.066	0.116
hori-right	0.044	0.097	0.023	0.026	0.048	0.117	0.152	0.125	0.058
hori-left	0.015	0.019	0.01	0.006	0.013	0.023	0.026	0.077	0.023
dia-down-right	0.166	0.134	0.043	0.109	0.166	0.061	0.106	0.105	0.099
dia-down-left	0.084	0.05	0.009	0.032	0.073	0.024	0.042	0.052	0.07
dia-up-right	0.038	0.136	0.239	0.126	0.049	0.093	0.077	0.117	0.061
dia-up-left	0.02	0.005	0.028	0.014	0.007	0.027	0.004	0.025	0.001
vert-out	0.066	0.049	0.067	0.095	0.051	0.093	0.063	0.049	0.071
hori-out	0.111	0.099	0.083	0.078	0.053	0.163	0.106	0.073	0.092
dia-out-up-right	0.033	0.017	0.071	0.056	0.029	0.066	0.043	0.051	0.019
dia-out-up-left	0.045	0.022	0.018	0.021	0.015	0.027	0.028	0.028	0.025
vert-in	0.006	0.019	0.006	0.004	0.028	0.015	0.02	0.02	0.049
hori-in	0.023	0.032	0.016	0.03	0.043	0.052	0.054	0.023	0.108
spiral-out	0.094	0.097	0.135	0.145	0.058	0.077	0.066	0.1	0.054
spiral-in	0.055	0.079	0.038	0.059	0.147	0.061	0.104	0.034	0.127

	ab	an	auf	aus	ein	mit	nach	vor	zu
vert-up	0.017	0.049	0.201	0.024	0.005	0.017	0.023	0.057	0.011
vert-down	0.128	0.049	0.047	0.063	0.136	0.015	0.038	0.036	0.099
hori-right	0.051	0.181	0.022	0.047	0.05	0.079	0.199	0.174	0.125
hori-left	0.019	0.031	0.008	0.024	0.038	0.012	0.051	0.089	0.053
dia-down-right	0.177	0.061	0.029	0.125	0.06	0.03	0.069	0.074	0.103
dia-down-left	0.076	0.018	0.005	0.046	0.042	0.009	0.025	0.011	0.036
dia-up-right	0.057	0.119	0.238	0.111	0.086	0.071	0.068	0.124	0.063
dia-up-left	0.011	0.016	0.021	0.015	0.014	0.021	0.004	0.023	0.015
vert-out	0.038	0.061	0.094	0.045	0.051	0.066	0.045	0.069	0.059
hori-out	0.073	0.061	0.072	0.102	0.05	0.206	0.072	0.049	0.038
dia-out-up-right	0.029	0.037	0.024	0.038	0.011	0.05	0.033	0.036	0.007
dia-out-up-left	0.036	0.014	0.01	0.014	0.013	0.032	0.03	0.018	0.014
vert-in	0.017	0.04	0.038	0.012	0.029	0.037	0.025	0.025	0.046
hori-in	0.034	0.056	0.01	0.019	0.095	0.085	0.009	0.026	0.114
spiral-out	0.136	0.138	0.134	0.232	0.077	0.191	0.207	0.132	0.071
spiral-in	0.101	0.07	0.046	0.083	0.242	0.076	0.101	0.057	0.145

Figure 7: Concept image selection across particles and BV domains.

preference for HORI-IN. Similarly, PVs composed of Sound BVs and particles *aus, ein, mit, nach, zu* inherit the strong preferences for spirals from the BVs, with *an, nach, vor* at the same time showing strong preferences for HORI-RIGHT. For PVs composed of MnT BVs, where already the concept image preferences for the BVs were less skewed than for the other two domains, it seems that also the respective PVs do not exhibit specific domain-dependent concept image preferences.

Across domains, the PVs with particles *ab, auf, nach, vor* appear to contribute rather constant meaning components: the most strongly selected concept images tend to be consistent across BV source domains and largely correspond to the overall strongest concept images in Figure 4. PVs with particles *an* and *auf* represent constants in a different way: in comparison to the other particle types, they seem to be more flexible in their meaning contribution, i.e., they do not show particularly strong preferences for specific concept images but similarly strong preferences for a range of concept images. Nevertheless, also these more constant particle meanings are influenced by the BV domains; for example, *ab* shows a strong preference for SPIRAL-OUT when combined with Sound BVs; *an* shows a strong preference for HORI-IN when combined with Force BVs; *auf* shows a strong preference for VERT-UP when combined with Sound BVs and only a loose preference for DIA-UP-RIGHT when combined with Force BVs; *nach* and *vor* show strong preferences for spirals when combined with Sound BVs and no strong preferences when combined with MnT BVs.

4 Discussion

In the remainder of this article, we refer the analyses in the previous section back to our hypotheses about particle meanings and particle concepts (Section 4.1) before we explore the role of the BV source domains (Section 4.2) and go into detailed meaning investigations regarding the particle *ab* (Section 4.3).

4.1 General analysis of particle concept hypotheses

The experiment participants associated *auf* and *ab* with the vertical arrows (VERT-UP and VERT-DOWN) and also with the corresponding diagonal versions pointing to the right: DIA-UP-RIGHT and DIA-DOWN-RIGHT, as predicted. The respective diagonal arrows pointing to the left were not chosen, which is an indication for the involvement of the horizontal time dimension. The particle *an* was, as predicted, most strongly associated with the HORI-RIGHT concept image; the additionally predicted DIA-UP-RIGHT concept image achieved a secondary preference.[3] *nach* and *vor* were strongly associated with the HORI-RIGHT concept image, which again indicates a reference to the time dimension. Since most *nach* and *vor* readings have a temporal component, a derivation of the basic particle concept from the time domain instead of the space domain should therefore be considered as an explanation.

In the case of *aus*, the SPIRAL-OUT concept image was selected most often. This can be explained by the strong association of the particle's prevalent meaning refering to a *container* image schema necessary for assigning a direction to *aus*. Since this experimental concept image setting consisted only of two-dimensional arrows, we can however only speculate about the relevance of the container representation. In contrast, *ein* was – in accordance with our assumptions – associated with VERT-DOWN (next to SPIRAL-IN), although these directions also require the notion of a container. In order to conceptualise an outside area, as necessary for many *aus* PV readings, it might be sufficient to think of a single wall in order to distinguish between an outside and an inside area. This could explain why *ein* received – in contrast to *aus* – stronger preferences for the predicted concept images based on the constraint of the existence of an imaginary container.

The particle *mit* was most strongly associated with the HORI-OUT concept image, in accordance with our assumptions. *zu* was not linked to DIA-UP-RIGHT, which we considered as possible concept representation for the intentional readings with an abstract goal. The strongest selection was in favour of the double-arrow concept image HORI-IN, followed by SPIRAL-IN, thus suggesting that a different sense of the particle was more salient in the contexts of the selected BVs. For example, for the PVs *zuzerren* 'to drag until closed' and *zustopfen* 'to plug' the particle introduces a closure relation, which is connected to the also chosen VERT-DOWN. However, the *zu*-PVs based on the abstract Sound BVs were also associated with these concept images, which at first sight does not fit the concrete closure notion. Here, it seems to be more likely that the selection for SPIRAL-IN does not represent the particle meaning, but the meanings of the Sound BVs. Together with the choice of HORI-IN as in *zudröhnen* ([*zu*]+'to drone/get stoned'), this points to an interpretation of *zu* as an abstract closure, where the closure is understood as the impairment of auditory perception, as realised through the very dominant and constant sound provided by the BV *dröhnen*. In this interpretation, each arrow head of HORI-IN conceptually points to one ear.

[3]Our results regarding *auf* and *an* are also in accordance with the insights of a lexical decision experiment presented by Frassinelli et al. (2017), which indicated that the particles have a predominant vertical/horizontal directionality, respectively.

4.2 Analysis of BV source domains

Figure 6 suggested that the BV source domains were associated with different preferences for concept images, although none of the BV classes is directional from a lexical semantic perspective. We believe that the associations between source domains and concept images thus indicate conceptual relations to directionality.

The MnT domain with its concrete BVs provides strong preferences for the concepts VERT-DOWN, DIA-DOWN-RIGHT, VERT-OUT, HORI-OUT and SPIRAL-OUT. The associations with HORI-OUT and SPIRAL-OUT can be explained with the visually clearly defined and easily imaginable manners of movement of the BVs *schleifen* 'to sand', *sägen* 'to saw', *spitzen* 'to sharpen', etc., whereas the associations to VERT-DOWN, VERT-OUT and DIA-DOWN-RIGHT can be traced back to the manners of movements of *hämmern* 'to hammer', *graben* 'to dig', *schaufeln* 'to shovel/dig', etc. However, the question arises why only the downward-pointing concept images were chosen and not the upward-oriented ones. We approach the question on a theoretical semantic basis. The BVs are denominal action verbs, either derived from an instrument (such as a shovel, a hammer, a fork) or from an intended result (such as a grave), and describe a repetitive motion. The involved motion has at least two changes of directions, marking the extreme points of the movement. The direct objects of MnT verbs typically refer to one of those extreme points, as in example (39), where *schaufeln* refers to the area beneath the ground which lies below our usual perceptual horizon. This idea corresponds to Lachmair et al. (2016)'s research which shows that words trigger specific spatial locations. Other frequent arguments of *schaufeln*, such as *hole* and *soil*, also refer to such a "down" area, as in examples (40) and (41). Here, the motion is spanned between the initial position of the instrument and the position of the affected area. In the examples (39–41), the direction of the shovel motion is defined between the initial "up" location of the shovel and the "down" location of the ground, thus justifying the downward concept images over upward concept images.

(39) Karin schaufelt einen Graben.
Karin dig a ditch
'Karin digs a ditch.'

(40) Karin schaufelt ein Loch.
Karin dig a hole
'Karin digs a hole.'

(41) Karin schaufelt Erde.
Karin shovel soil
'Karin shovels soil.'

On the contrary, the Sound BVs, which are the most abstract verbs in this data set, were not linked to many of our simple directional concept images. They were mainly associated with the spirals, thus suggesting a mental mapping to the prototypical picture of a sound wave. That is, the underlying idea of the spiral as concept representation was a uniform expansion, which matches to the motion behaviour of sound waves. In addition, there was some preference for the double-headed arrows HORI-OUT and VERT-OUT as concept images for the BVs with a repetitive sound character. This can be attributed to the strongly prototypical manner of sound production actions, which are usually caused by an up-and-down motion as in drumming, or a left-to-right motion as in clapping. This means that the Sound BVs, which are not directional from a lexical semantic perspective, were analysed as conceptually directional. This clear-cut mapping between spiral and sound wave as well as between double-headed arrow and manner-of-production of repetitive sounds, allows distinguishing between the concept images triggered by the BVs and the concept images triggered by the particle, which provides insight into the composition process and explains the low compatibility between particle types and Sound BVs, as reflected in the high number of neoPVs in Figure 3 (page 19).

The Force BVs describe events which are mainly defined through the interplay of two concrete arguments. In comparison to MnT verbs, the Force verbs are less concrete, but at the same time they are also less abstract than the Sound verbs. The importance of the arguments shows up in the preference for the concepts HORI-IN and VERT-IN, which both have two arrow heads. The concept images are thereby similar to the vectors used in the schematic representations of forceful verbs by Zwarts (2010).

4.3 Analysis of particle *ab*

In the last part of our analyses we focus on concept image preferences regarding one specific particle type. We choose *ab*, the particle which is strongly associated with a downward direction.

Figure 8 shows the distribution over concept images for PVs with particle *ab* across BV source domains. In all three domains, the participants agreed on the two DOWN concepts (i.e., VERT-DOWN and DIA-DOWN-RIGHT), although the PVs in the experiment were assigned to different lexical semantic classes by Kliche (2011).

	Force	MnT	Sound
vert-up	0.003	0.028	0.017
vert-down	0.148	0.172	0.128
hori-right	0.049	0.044	0.051
hori-left	0.056	0.015	0.019
dia-down-right	0.153	0.166	0.177
dia-down-left	0.071	0.084	0.076
dia-up-right	0.069	0.038	0.057
dia-up-left	0.02	0.02	0.011
vert-out	0.044	0.066	0.038
hori-out	0.092	0.111	0.073
dia-out-up-right	0.019	0.033	0.029
dia-out-up-left	0.028	0.045	0.036
vert-in	0.067	0.006	0.017
hori-in	0.104	0.023	0.034
spiral-out	0.035	0.094	0.136
spiral-in	0.042	0.055	0.101

Figure 8: Concept image selection for *ab* across BV domains.

Looking into specific PVs with strong preferences for the two DOWN concept images, an example instance of an unknown PV is represented by *abhämmern* ([ab]+'to hammer'), cf. example (42). We assume that this PV was understood as a separation performed by a hammering force. *abquetschen* 'to squeeze off' in example (43) is an instance of a well-known PV where the particle is combined with a Force BV, describing a force that causes a SEPARATION. The well-known PV *abklingen* combines the particle with a Sound BV; literally, it describes that a sound fades away, but it is more common in its metaphorical reading of approaching the end of an event together with a value decrease, as in example (44). The approaching of the end of the storm can be conceptualised as decreasing intensity within both the value and the time dimensions, or can alternatively be interpreted only temporally, as a slowly ending process. However, in comparison to the previous examples no causer is involved, suggesting that the downward meaning is conceptually connected to *ab*, even if from a lexical semantic perspective only the result is expressed.

(42) Karin hämmert den rostigen Nagel ab.
Karin hammer the rusty nail [ab]
'Karin detaches the rusty nail by hammering.'

(43) Karin hat sich ihren Finger abgequetscht.
Karin has herself her finger [ab]+squeeze
'Karin has crushed her finger.'

(44) Der Sturm klingt ab.
The storm sound [ab]
'The storm is about to stop.'

The examples illustrate that even though the contexts are rather different, the meanings of the particle can in all cases be traced back to a downward direction, either causing or being caused by a separation, varying according to the constraints. We argue that the downward concept is not only the basic meaning component, but the prototypical reading for the particle *ab*.

5 Conclusion

In this article, we have demonstrated that directional concepts, visually represented as arrow pictographs, can be applied to a systematically composed set of German particle verbs and their underlying base verbs. Furthermore, the selected concept images were mostly in accordance with the particle directions predicted on the basis of example sentences, lexical-semantic classifications and spatial experience, and largely stable for well-known vs. unknown particle verbs. Thus, direction is a concept that should be taken into account as a part of the PV composition process and the contribution of the particle to the particle verb meaning.

Understanding potential particle fundamentals as concepts, instead of meanings, has the advantage that senses are not considered as discrete, static classifications requiring plenty of compromises or borderline cases. Concepts as basic components are flexible and can easily be adjusted to various contexts. Thereby, classes of similar contextual requirements trigger similar concept adjustments, and hence are assumed to enforce a specific particle sense.

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Appendix

Table 2: Selected 30 base verbs and their source domains. All these base verbs were systematically composed to a total of 270 particle verbs by prefixing them with the nine constituent particle types *ab, an, auf, aus, ein, mit, nach, vor, zu.*

Base verb	Source domain
biegen	Force
brechen	Force
brummen	Sound
donnern	Sound
drängen	Force
dröhnen	Sound
gabeln	Machines and Tools
graben	Machines and Tools
heulen	Sound
hämmern	Machines and Tools
jaulen	Sound
klappern	Sound
klingen	Sound
kämmen	Machines and Tools
pressen	Force
quetschen	Force
rattern	Sound
schalten	Machines and Tools
schaufeln	Machines and Tools
schleifen	Machines and Tools
schrauben	Machines and Tools
spitzen	Machines and Tools
stauen	Force
stopfen	Force
summen	Sound
sägen	Machines and Tools
wummern	Sound
zerren	Force
zwingen	Force
zwängen	Force